(NASA-CR-151625) BENEFIT EVALUATION OF SPACE PROCESSING OF BIOLOGICAL MATERIALS Final Report (ECON, Inc., Princeton, N. J.) 192 p HC A09/MF A01 CSCL 06C

N78-17120

Unclas
G3/12 04509

BENEFIT EVALUATION OF SPACE PROCESSING OF BIOLOGICAL MATERIALS

FINAL REPORT

77-271-2

Econ
INCORPORATED

NINE HUNDRED STATE ROAD
PRINCETON, NEW JERSEY 08540
609 924-8778

FINAL

BENEFIT EVALUATION OF SPACE PROCESSING OF BIOLOGICAL MATERIALS

CONTRACT NAS-9-15338

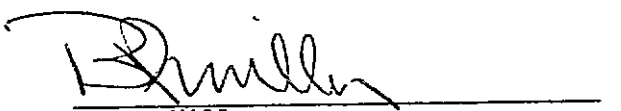
FINAL REPORT

December 1977

NOTE OF TRANSMITTAL

This study of the potential economic and social benefits of the space processing of three biological substances was performed for the Lyndon B. Johnson Space Center, National Aeronautics and Space Administration, under Contract NAS-9-15338. The NASA Technical Officer for this study was Mr. Herbert Greider.

The ECON study team consisted of Ms. Celia Drumheller, Mr. Keith Lietzke, Mr. B. P. Miller, Mr. Jay Perrine and Dr. Mark Thompson. Ms. Drumheller and Mr. Lietzke performed the study of Beta cells, Mr. Perrine performed the study of lymphocytes and urokinase-producing cells and Dr. Thompson examined the methodologies used for the evaluation of the economic and social impacts of biomedical research. Mr. B. P. Miller was Project Manager for this study.



B. P. Miller

TABLE OF CONTENTS

		Page
	Note of Transmittal	ii
1.	Summary and Recommendations	1
2.	Introduction	15
3.	Procedures and Assumptions for Estimation of the Value of Human Capital	45
4.	Benefits of Lymphocyte Subgroup Separation and Classification for Treatment of End Stage Renal Disease and Benefits of the Separation of Urokinase-Producing Cells for Treatment of Pulmonary Embolisms	57
	4.1 Background	59
	4.2 End Stage Renal Disease	65
	4.3 Thromboembolic Diseases	75
	4.4 Summary of Benefits for Treatment of End Stage Renal Disease and Pulmonary Embolisms	85
5.	Benefits of the Separation of Beta Cells for the Treatment of Diabetes	89
	Appendix A Human Capital Procedures/Assumptions	145
	Appendix B Cost Data for Treatment of End Stage Renal Disease	149
	Appendix C Cost Data for Treatment of Pulmonary Embolism	155
	Appendix D Computer Program Listing for the Model of ESRD and Pulmonary Embolism	161
	Appendix E Diabetes Transitional Probability Model Program Computer Listing	169
	Appendix F Cost of Diabetes Treatment	175
	Appendix G Cost of Diabetic Complication Care	183

SUMMARY AND RECOMMENDATIONS

OBJECTIVES OF STUDY

The objectives of this study are to evaluate and select methodologies for use in estimating the potential economic and social benefits of applications of the NASA space bioprocessing program. The selected methodologies are then to be used to estimate the potential benefits that could result from the successful research and clinical application of three candidate space bioprocessing substances.

The central questions to be answered in this study are:

1. What are the accepted methodologies for the evaluation of the benefits of medical research?

2. What are the estimated potential benefits that could result from a successful research and clinical application program for specified candidate substances for space bioprocessing?

OBJECTIVES OF STUDY

- SURVEY METHODOLOGIES USED TO ESTIMATE BENEFITS OF MEDICAL RESEARCH. RECOMMEND ACCEPTABLE METHODOLOGIES FOR THE EVALUATION OF THE ECONOMIC AND SOCIAL BENEFITS OF CANDIDATE SUBSTANCES FOR NASA SPACE BIOPROCESSING PROGRAM.

- ESTIMATE THE POTENTIAL BENEFITS OF SUCCESSFUL RESEARCH AND CLINICAL APPLICATION OF THREE SUBSTANCES THAT ARE CANDIDATES FOR SPACE BIO-PROCESSING. THE THREE CANDIDATE SUBSTANCES ARE:

  + SEPARATION AND CLASSIFICATION OF LYMPHOCYTE SUBGROUPS
  + SEPARATION OF UROKINASE-PRODUCING CELLS
  + SEPARATION OF BETA CELLS.

CANDIDATE SUBSTANCES AND APPLICATIONS STUDIED

The purpose of the work described in this report is to provide a rational analytical basis for the evaluation of the potential benefits of the processing of biological materials in space. These quantitative evaluations could then be used by decision makers, in conjunction with other information, as a basis for the selection of candidate projects. In the work performed to date, a preliminary evaluation has been made of the potential benefits of three candidate space processed biological materials. The three materials investigated are human lymphocytes, urokinase and Beta cells. In the case of human lymphocytes, electrophoresis is to be used to separate and classify lymphocyte subgroups in order to improve the matching of donors and recipients for kidney transplantation. It is believed that lymphocytes play an important role in immune functions, and that the results of the proposed research, if successful, could lead to improved kidney transplant acceptance. Urokinase is a drug which appears to be able to dissolve blood clots, and may be useful in the treatment of thromboembolic diseases. Urokinase can either be extracted from human urine or from kidney cells. Urokinase produced from human urine is not used in the United States because of purity problems with fever-producing precursors which are difficult to remove from the urine. The alternative technique for the production of urokinase is to separate urokinase-producing cells from all other kidney cells. It has been theorized that using electrophoretic separation in space, kidney cells could be separated with respect to cell function, and returned to earth in a viable condition. Then, the urokinase-producing cells would be propagated in earth-based facilities.

Beta cells found in the human pancreas could provide a highly effective means for the treatment of juvenile-onset diabetes. As in the case of lymphocytes and urokinase, it is believed that electrophoretic separation in space could be used to extract Beta cells which could then be injected into a diabetic patient. If successfully accomplished, the use of Beta cells could eliminate many of the complications that arise from the use of bovine and porcine insulin for the treatment of diabetes.

CANDIDATE SUBSTANCES AND APPLICATIONS STUDIED

SUBSTANCE	SPACE PROCESS	MECHANISM	CLINICAL APPLICATION	CLINICAL IMPACT
BETA CELLS	SEPARATE BETA CELLS FROM OTHER PANCREATIC CELLS	ELECTROPHORESIS	INSULIN-DEPENDENT DIABETICS	REDUCE INCIDENCE AND SEVERITY OF COMPLICATIONS OF DIABETES
LYMPHOCYTES	SEPARATE AND CLASSIFY LYMPHOCYTE SUBGROUPS	ELECTROPHORESIS	KIDNEY TRANSPLANTS IN END-STATE RENAL DISEASE PATIENTS	IMPROVE SUCCESS RATE OF TRANSPLANTS
UROKINASE	SEPARATE UROKINASE-PRODUCING CELLS FROM OTHER KIDNEY CELLS	ELECTROPHORESIS	THROMBOEMBOLIC DISEASES, SPECIFICALLY, PULMONARY EMBOLISMS	LYSE (DISSOLVE) BLOOD CLOTS

STUDY APPROACH

The approach used in this study is delineated in the opposite chart.

An extensive review of the literature of the economics of medical research was performed to identify the techniques used for the estimation of benefits of medical research. This study of methodologies identified the fact that it is necessary to consider both the economic and social benefits of medical research. The economic (or direct benefit) results from the reduced cost of a disease treatment which would yield an equal or greater productive life expectancy when compared to present treatments of the same disease. The social (or indirect benefit) stems from the possible extension of life and increased productivity from improved health resulting from the new disease treatment. Using available statistics on the current methods of treatment and expert estimates on the new methods of treatment, the benefits of the proposed research are calculated as the differences between the costs and productive life expectancies associated with existing treatment systems, and similar characteristics associated with the new treatment systems that could result from the processing of biological materials in space.

STUDY APPROACH

- REVIEW LITERATURE ON METHODOLOGIES FOR ESTIMATION OF ECONOMIC AND SOCIAL BENEFITS OF MEDICAL RESEARCH
- SELECT METHODOLOGIES FOR EVALUATION OF ECONOMIC AND SOCIAL BENEFITS THAT ARE WIDELY USED AND GENERALLY ACCEPTED
- SELECT CLINICAL APPLICATIONS FOR THE THREE CANDIDATE SUBSTANCES FOR SPACE BIOPROCESSING
- OBTAIN MORTALITY, MORBIDITY AND COST STATISTICS FOR CURRENT TREATMENT OF SELECTED CLINICAL APPLICATIONS
- OBTAIN ESTIMATES OF IMPACT OF CANDIDATE SUBSTANCES ON MORBIDITY, MORTALITY AND COST OF TREATMENT
- ESTIMATE THE POTENTIAL ECONOMIC AND SOCIAL BENEFITS OF THE THREE CANDIDATE SUBSTANCES USING THE SELECTED METHODOLOGIES

SUMMARY OF RESULTS

This study has shown that several methodologies are used in the fields of health care economics, insurance and systems analysis to evaluate the benefits of improved disease treatment systems. ECON has selected a transitional probability (Markovian) methodology to model the disease treatment and to provide insight into the impact of new treatment system on morbidity, mortality, as well as the duration and cost of treatment. Using the model of the disease treatment system, the results are quantified as changes in the cost of treatment of the disease and its complications and as increased income as a result of an extended productive lifetime.

The techniques used in this analysis (transitional probability modeling and present value of future earnings) are well established and widely accepted in the health care economics community.

SUMMARY OF RESULTS

- STUDY HAS IDENTIFIED ACCEPTABILITY OF TRANSITIONAL PROBABILITY METHODOLOGY AND VALUE OF HUMAN CAPITAL APPROACH TO ESTIMATION OF ECONOMIC AND SOCIAL BENEFITS OF IMPROVED DISEASE TREATMENT

- DEVELOPED OR IMPROVED OPERATING BENEFIT MODELS FOR THREE CANDIDATE SUBSTANCES AND CLINICAL APPLICATIONS:

  + END STAGE RENAL DISEASE (LYMPHOCYTE SUBGROUP SEPARATION)
  + PULMONARY EMBOLISMS (SEPARATION OF UROKINASE PRODUCING CELLS)
  + HUMAN DIABETES (SEPARATION OF BETA CELLS)

- ESTIMATED THE POTENTIAL ECONOMIC AND SOCIAL BENEFITS OF SPACE BIOPROCESSING IN EACH OF THE ABOVE DISEASE TREATMENTS

SUMMARY OF BENEFITS

This figure summarizes the quantified economic and social benefits for the three candidate substances and clinical applications studied. For the purpose of this study, it was assumed that the new treatment systems would be available for initial use in 1985. It should be noted that the total benefits are given for the lifetime of the initial patient population that begins treatment in 1985, and that additional benefits could be realized as the new treatment systems are used for additional patients in each successive year.

Annual benefits for each year of treatment from disease onset to patient death have been discounted by 6 percent per year to the initial year to reflect the time value of money. Aggregate benefits are expressed in 1985 dollars since this is the assumed first year of operation. A 6 percent inflation rate was used. The use of 6 percent for both discount and inflation rates is purely coincidental.

SUMMARY OF BENEFITS
(ALL DOLLAR VALUES ARE 1985$ AT 6% DISCOUNT AND INFLATION RATES)

DISEASE TREATMENT	CANDIDATE SUBSTANCE	NUMBER OF PATIENTS PER YEAR BECOMING AFFLICTED	BENEFIT PER PERSON FROM TIME OF DISEASE ONSET*	YEARS OF LIFE PER PERSON EXTENDED BY THE SPACE-BASED ENDEAVOR	AVERAGE PER PERSON PRIVATE BENEFIT FROM REDUCED TREATMENT COSTS	AVERAGE PER PERSON PRIVATE BENEFIT FROM EXTENDED LIFE (EARNINGS)	ESTIMATED TOTAL BENEFIT FOR LIFETIME OF INITIAL TREATMENT POPULATION	ARE OTHER DISEASE TREATMENTS POTENTIALLY IMPACTED BY THIS SPACE-PROCESSING SPECIMEN
END STAGE RENAL DISEASE	LYMPHOCYTE SEPARATION	10,000	$124,222	3.39	$11,667	$22,670	$ 1,200,000,000	YES, OTHER TRANSPLANTS AND POSSIBLY CANCER
PULMONARY EMBOLISM	UROKINASE	750,000	$ 4,052	1.56	$ - 85	$ 4,137	$ 3,000,000,000	YES, OTHER THROMBO-EMBOLIC DISEASES
DIABETES**	BETA CELLS	1,240,000***	$ 23,900	5.2	$11,040****	$12,860	$29,600,000,000	NO

*INCLUDES PRIVATE AND PUBLIC SECTOR BENEFITS FOR ESRD. THERE ARE NO PUBLIC SECTOR BENEFITS FOR PULMONARY EMBOLISM AND DIABETES.

**ASSUMES BETA CELL TRANSPLANT.

***THIS IS THE NUMBER OF DIABETICS WHO COULD CONSTITUTE THE TREATMENT POPULATION IN THE FIRST YEAR. THE POPULATION IN SUCCESSIVE YEARS WOULD BE INCREASED BY THE INCREMENTAL NUMBER OF NEW JUVENILE-ONSET DIABETICS DIAGNOSED IN THAT YEAR.

****INCLUDES DIABETIC TREATMENT AND DIABETIC COMPLICATIONS COST BENEFITS.

RECOMMENDATIONS

The results of this study conclusively demonstrate that it is possible to use analytical techniques to quantify the potential economic and social benefits of new treatment systems that could be developed as a result of successful space bioprocessing experimentation. The specific benefit estimates are highly sensitive to the cost, morbidity and mortality input data used in the models. For this reason, it is recommended that the benefit estimates be considered to be preliminary until further work can be done to improve the quality of the input data.

Several other substances are also candidates for space bioprocessing experiments. It is recommended that this benefit study be continued to examine the potential benefits of additional candidate substances, thus providing a basis for comparing experiments that could compete for limited resources.

As the reader of this report will note, this is not a benefit/cost study. The costs of the space research, ground research and clinical trials leading to an approved pharmaceutical product have not been considered in this study. Moreover, the benefits assume that the space research and subsequent clinical trials will be fully successful. In order to rate the candidate substances, it is recommended that the additional dimensions of cost and probable outcomes of the research and development programs be considered in further studies of the candidate substances.

RECOMMENDATIONS

- CONTINUE STUDIES TO REFINE COSTS AND PROBABILITIES OF SUCCESS OF THE CANDIDATE SPACE BIOPROCESSING PROJECTS AND OTHER COMPETITIVE METHODS OF ACHIEVING THE SAME TREATMENT OBJECTIVES

- MODEL DISEASE TREATMENTS AND ESTIMATE BENEFITS FOR OTHER SEPARATION CANDIDATES AND CLINICAL APPLICATIONS SUCH AS:
  - + STEM CELLS - ESTABLISHMENT OF IMMUNE SYSTEM FOR SUBSEQUENT ORGAN TRANSPLANT
  - + GRANULOCYTES - TRANSFUSION FOLLOWING CHEMOTHERAPY AND/OR IRRADIATION FOR ACUTE MYELOBLASTIC LEUKEMIA
  - + MEGAKARYOCYTES - TRANSFUSION FOLLOWING CHEMOTHERAPY AND/OR IRRADIATION TREATMENT FOR TUMOR CANCERS
  - + PEPTIDE HORMONES - POST STEROID THERAPY

INTRODUCTION

OBJECTIVES: CONTRACT NAS-9-15338

In a previous study for NASA Headquarters, ECON developed and applied a methodology for the evaluation of the potential benefits of space-based research in lymphocyte subgroup separation, and the separation of urokinase-producing cells.[1]

The present study has three objectives. The first is to evaluate the acceptance of the methodology used for the estimation of economic benefits in our earlier study within the community of economists and public policy analysts who work on the evaluation of biomedical research. A second objective is to reassess the economic benefits and to evaluate the social benefits of lymphocyte subgroup separation and the separation of urokinase-producing cells. The third objective is to evaluate the economic and social benefits of the separation of Beta cells.

---

[1] Preliminary Benefit Analysis of Biological Space Processing. ECON, Inc., 1 September 1976.

OBJECTIVES: CONTRACT NAS-9-15338

1. EVALUATE THE ACCEPTABILITY WITHIN THE MEDICAL RESEARCH ECONOMICS COMMUNITY OF THE METHODOLOGY FOR BENEFIT EVALUATION PREVIOUSLY DEVELOPED AND APPLIED BY ECON TO SPACE BIOPROCESSING PROBLEMS UNDER CONTRACT TO NASA HEADQUARTERS.

2. REESTIMATE THE ECONOMIC BENEFITS AND QUANTIFY THE SOCIAL BENEFITS IN THE TWO AREAS OF SPACE BIOPROCESSING WHERE ECON HAS PREVIOUSLY ESTIMATED THE ECONOMIC BENEFITS. THE TWO AREAS ARE LYMPHOCYTE SUBGROUP SEPARATION AND CLASSIFICATION, AND THE SEPARATION OF UROKINASE-PRODUCTION CELLS.

3. ESTIMATE THE ECONOMIC AND SOCIAL BENEFITS FOR SEPARATION OF BETA CELLS IN SPACE FOR APPLICATION TO TREATMENT OF DIABETES.

BACKGROUND

In our previously referenced study for NASA Headquarters[1], two promising candidate substances for space bioprocessing were selected for benefit evaluation. These two substances were lymphocytes and urokinase. In the case of lymphocytes, ground-based research has led to the classification of two subgroups, and the objective of the space-based research is to further separate and extend the classification process within the two presently identified subgroups. At the present time, using ground-based techniques, urokinase-producing cells cannot be separated from other kidney cells. In both instances, electrophoretic separation in space has been proposed as the mechanism to effect separation. The clinical application selected for study in connection with lymphocyte subgroup classification, is the matching of donors and recipients for kidney transplantation; while the application selected for urokinase is the reduction of blood clots associated with pulmonary embolisms. While other possible applications exist for these two substances, these two applications represent areas where immediate progress could be made if the space-based research is successful.

This preliminary study concluded that very large economic benefits could result from successful lymphocyte subgroup separation. During this earlier study, it was also determined that it is possible that urokinase production costs could be reduced as a result of the successful separation of urokinase-producing cells, thus leading to increased availability and widespread use of urokinase in the treatment of thromboembolic diseases. This, in turn, could lead to a reduction in the number of deaths from pulmonary embolisms, and could possibly reduce the need for some surgical procedures and thus reduce the length of hospital stay.

[1]Preliminary Benefit Analysis of Biological Space Processing, ECON, Inc., 1 September 1976.

BACKGROUND

- PREVIOUS STUDY OF LYMPHOCYTE SUBGROUP SEPARATION AND SEPARATION OF UROKINASE-PRODUCING CELLS USED TRANSITIONAL PROBABILITY TECHNIQUES TO ESTIMATE ECONOMIC BENEFITS

SUBSTANCE	LYMPHOCYTES	UROKINASE
SPACE PROCESS	SEPARATE AND CLASSIFY SUBGROUPS	SEPARATE AND CONCENTRATE UROKINASE-PRODUCING CELLS
MECHANISM	ELECTROPHORISIS	ELECTROPHORISIS
CLINICAL APPLICATION	KIDNEY TRANSPLANTATION	THROMBOEMBOLIC DISEASES
CLINICAL IMPACT	IMPROVE TRANSPLANT ACCEPTANCE	LYSE BLOOD CLOTS

THE NEED FOR QUANTIFIED ESTIMATES OF BENEFITS

The common starting point for analysts of biomedical research is the need to quantify estimates of benefit. This need is apparent in decision making. In annual budget processes, research projects compete against each other and with other social priorities for limited resources. Whenever one project is funded in preference to another of equal cost, it is implicitly rated higher on the scale of anticipated benefits. To date, that scale has primarily reflected scientific merit, although recent years have seen efforts to bring encompassing societal priorities to bear.

As conceptual difficulties, data deficiencies, and individual resistance have hampered explicit quantification of the rationale behind funding decisions, they continue to be made on an ad hoc basis. For so long as the obstacles to quantification endure, opportunities for inconsistency persist. Quantifying the expected benefits forces decision makers to adopt a consistent comprehensible scale (1) for explaining and justifying their actions, (2) for enabling systematic adherence to relevant priorities and thereby avoiding suspicions of unfairness, and (3) for relating resource commitments to anticipated return.

THE NEED FOR QUANTIFIED ESTIMATES OF BENEFITS

- COMPETITION FOR LIMITED RESOURCES

- DECISIONS BASED UPON SCIENTIFIC MERIT AND SOCIETAL PRIORITES

- ENCOURAGES DECISION MAKERS TO ADOPT A CONSISTENT AND UNDERSTANDABLE SCALE FOR
    - + EXPLAINING ACTIONS
    - + MAINTAINING ADHERENCE TO PRIORITIES
    - + RELATING RESOURCE COMMITMENTS TO EXPECTED RESULTS

DEFINITION OF ECONOMIC AND SOCIAL BENEFITS

Two classes of benefits must be considered when the benefits of a proposed new method of disease treatment are to be evaluated. For the purpose of this study, these two classes of benefits are considered to be the economic (or direct) benefits and social (or indirect) benefits. The economic benefits are defined as those benefits that occur in the private and public sector from the changes in the cost of treatment of the disease and its complications. Social benefits are defined as those benefits that result from decreases in mortality and/or morbidity as a result of the new treatment process. For example, prior to the use of penicillin, many bacterial infections required hospitilization and long periods of convalescence. With the use of penicillin, an economic benefit results as the cost of treatment of bacterial infection has been decreased. Further, a social benefit also results as the use of penicillin has reduced the incidence of death and periods of disability from bacterial infection.

The purpose of a benefit evaluation study is to express these benefits in measurable quantities such as dollars and years of life extension.

DEFINITION OF ECONOMIC AND SOCIAL BENEFITS

- TWO BENEFIT COMPONENTS
  - + ECONOMIC - COST OF DISEASE TREATMENT
  - + SOCIAL - DECREASED MORTALITY AND/OR INCREASED PRODUCTIVITY
- PURPOSE OF BENEFIT EVALUATION IS TO CONVERT ABOVE TO SCALAR QUANTITIES
  - + DOLLARS
  - + YEARS

SOCIAL BENEFITS

An improved state of health is a social benefit which can be measured in several ways. The number of persons who avoid a premature death can be counted and a value placed on their lives. Death can be postponed for some period of time which can be measured. Regardless of whether life is extended there is often increased productivity from improved health, that is, people who might otherwise be debilitated could return to work. Most of these improvements can then be quantified in dollars or some scalar quantity such as average number of years of life extension. When these benefits are compared to other candidate substance benefits, a ranking is possible.

SOCIAL BENEFITS

- DECREASED MORTALITY
  - \+ AVOID DEATH FROM SERIOUS ILLNESS
  - \+ POSTPONE DEATH FOR N NUMBER OF YEARS IN SEMIHEALTHY STATE
- INCREASED PRODUCTIVITY
  - \+ IMPROVED HEALTH
  - \+ SHORTENED MEDICAL TREATMENT
- CONVERT ABOVE TO SCALAR QUANTITIES

KEY QUESTION

The key question to be addressed in the evaluation of social benefits is: What is the benefit of extending the life of a person who is afflicted with some specific disease? This question can be rephrased as: What is the benefit of extending the average life expectancy of a group of persons all afflicted with the same disease?

KEY QUESTION

WHAT IS THE BENEFIT OF EXTENDING A PERSON'S LIFE (OR GROUP OF PERSONS AFFLICTED WITH THE SAME DISEASE) N YEARS?

VALUING HUMAN LIVES

The concept of placing an economic value on reductions in mortality and morbidity is common to several professions. The techniques used in these professions were reviewed in order to select techniques for use in this study that have broad acceptance.

VALUING HUMAN LIVES

INVESTIGATED TECHNIQUES USED TO VALUE HUMAN LIVES FROM SEVERAL PROFESSIONAL PERSPECTIVES

- LAW
- INSURANCE
- ECONOMICS, ESPECIALLY HEALTH ECONOMICS
- SYSTEMS ANALYSIS OF MEDICAL RESEARCH BENEFITS

INSURANCE INDUSTRY APPROACH

The insurance industry was one of the first to place a value on a human life in order to sell insurance on the value obtained. The approach utilized is to sum all future earnings from the present until age 65, first subtracting costs for one's own consumption, and then discounting that amount to the present using a risk-free interest rate (about 4 percent). The concept is that a person, particularly a family breadwinner, should insure his life for an amount equal to the capitalized value obtained so that in the event of his death the family would obtain an income equal to that of the deceased if he had survived. This technique is called the capitalized human value method, or human capital technique.

INSURANCE INDUSTRY APPROACH

SUM ALL FUTURE EARNINGS TO AGE 65 (OR 62), SUBTRACT ONE'S OWN CONSUMPTION, AND THEN OBTAIN PRESENT VALUE OF THE NET USING A SUITABLE RISK-FREE INTEREST RATE.

(ONE SHOULD THEN OBTAIN INSURANCE EQUAL TO THIS AMOUNT TO PROVIDE THE SAME INCOME AS WOULD BE EXPECTED HAD THE INDIVIDUAL LIVED.)

LIFE VALUES FROM LEGAL JUDGMENTS

The courts have long been called upon to determine the value of a human who has been killed in a manner where fault can be proven, such as in a plane crash or auto accident. After the determination of guilt by legal methods, the decision has to be made on a pecuniary value in the wrongful death case. The award is generally made after expert testimony by an actuary or economist who in some manner calculates the present value (discounted) of expected future earnings and, depending on state laws, adds additional sums for such family losses as training of children. These awards are entirely dependent on the exact situation of the person at the time of death (age, income, family size, dependents, age of dependents, etc.).

LIFE VALUES FROM LEGAL JUDGMENTS

IN WRONGFUL DEATH CASES THE AWARD IS USUALLY DETERMINED BY:

- EXPERT TESTIMONY ON THE PRESENT VALUE OF EXPECTED FUTURE EARNINGS (FOR A CHILD, THE PROBABLE EARNINGS MINUS SUPPORT COSTS TO RAISE CHILD TO ADULTHOOD)
- PECUNIARY LOSS OF PRESENT AND PROBABLE FUTURE BENEFITS
  - \+ TRAINING, GUIDANCE AND ADVICE (ESPECIALLY OF CHILDREN)
  - \+ SOCIETY AND COMPANIONSHIP
- TOTAL AWARD QUITE DEPENDENT ON CONDITIONS AT TIME OF DEATH (INCOME, AGE, DEPENDENTS, ETC.)

ECONOMICS AND SYSTEMS ANALYSIS APPROACHES

Medical economics and systems analysis studies have utilized the four techniques listed on the opposite page. These techniques will be discussed on the following pages.

ECONOMICS AND SYSTEMS ANALYSIS APPROACHES

IN GOVERNMENT BENEFIT-COST AND MEDICAL RESEARCH FUNDING STUDIES, FOUR TECHNIQUES HAVE BEEN EMPLOYED:

1. HUMAN CAPITAL TECHNIQUE
2. IMPLICIT VALUE TECHNIQUE
3. LIFE-VALUE TECHNIQUE
4. WILLINGNESS-TO-PAY TECHNIQUE

HUMAN CAPITAL TECHNIQUE

The human capital technique, in which future earnings are discounted to obtain present values, is widely utilized. Tables are generated from government-supplied employment and income statistics so that all members of society are represented. This technique has by far the widest utilization. Medical studies generally make use of tables generated by Dorothy P. Rice, who is now the director of the National Center for Health Statistics. The criticisms against the use of this technique are that women, the elderly and minorities are unfairly valued and that income, in general, is no indicator of worth. This technique, in its many variations, is probably the most widely used.

HUMAN CAPITAL TECHNIQUE

PRESENT VALUE OF FUTURE EARNINGS, SOMETIMES SUBTRACTING PERSONAL CONSUMPTION

- MOST WIDELY USED TECHNIQUE
  - \+ MANY MEDICAL STUDIES UTILIZE TABLES AND TECHNIQUE ESTABLISHED BY D. P. RICE
- DATA WIDELY AVAILABLE
- UNEQUITABLE FOR WOMEN, MINORITIES, ELDERLY AND UNEMPLOYED

IMPLICIT VALUE TECHNIQUE

This technique obtains the value of human lives implicitly. This circular argument assumes that if each life saved by a new road intersection project was valued at $15,000, then the value of human lives must, in fact be $15,000. If an ejector seat for a military plane costs the equivalent of $1 million per expected life saved, do we use that value or the value implicit in the highway project? Were the values determined in 1970 good guidelines for 1985?

IMPLICIT VALUE TECHNIQUE

OBTAIN VALUE OF HUMAN LIVES IMPLICIT IN PREVIOUS GOVERNMENT PROJECTS

- CIRCULAR ARGUMENT
- WHICH PROJECTS?
  - VALUES MAY RANGE FROM 10,000 TO 1,000,000
- ARE PAST DECISIONS GUIDELINES FOR PRESENT EFFORTS?

LIFE-VALUE TECHNIQUE

The life-value technique utilizes life insurance purchases and/or court awards as the basis for valuing human life. If a person purchases only $15,000 of insurance, does that establish his/her life value? In like manner, which court cases should be chosen, the ones where the jury was liberal or very restrained? Little use is made of this technique.

LIFE-VALUE TECHNIQUE

UTILIZE INSURANCE PURCHASE OR COURT AWARD DECISIONS AS BASIS FOR VALUE OF HUMAN LIFE

- INSURANCE PURCHASED IS NOT AN INDICATION OF SELF-WORTH
- ACCEPTANCE OF $100,000 FOR AN ASSIGNMENT WITH ONE CHANCE IN FIVE OF DEATH CANNOT MEAN ACCEPTANCE OF CERTAIN DEATH FOR $500,000!
- WHICH COURT CASES SHOULD BE UTILIZED?
- LITTLE USE MADE OF THIS TECHNIQUE

WILLINGNESS-TO-PAY TECHNIQUE

Considerable interest is given this approach in economic literature. The drawback is that many surveys need to be conducted to establish this as an acceptable technique, a procedure too costly for most research projects needing this information. The one survey conducted produced values closely resembling the human capital approach. This technique has been only selectively utilized.

WILLINGNESS-TO-PAY TECHNIQUE

CONDUCT A SURVEY TO DETERMINE WHAT PRICE PEOPLE WOULD PAY TO CONDUCT RESEARCH TO ELIMINATE A SPECIFIC DISEASE AND EXTRAPOLATE LIFE VALUES

- ANSWERS FROM ONE SURVEY RESEMBLED HUMAN CAPITAL APPROACH
- TOO LITTLE EMPIRICAL EVIDENCE AVAILABLE TO SUPPORT THE TECHNIQUE
- NO INCENTIVE ON PART OF THE RESPONDENT TO PROVIDE TRUE PREFERENCES

PROCEDURES AND ASSUMPTIONS FOR ESTIMATION OF THE VALUE OF HUMAN CAPITAL

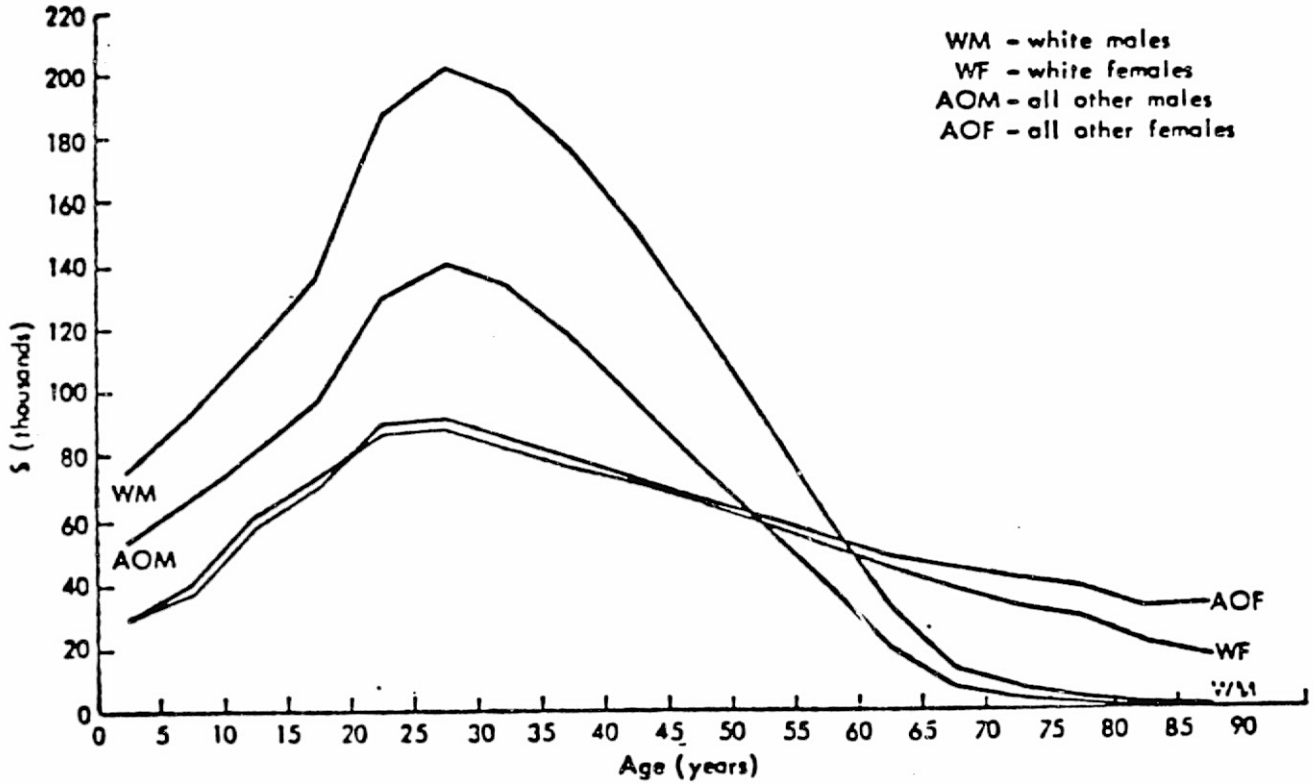
VALUE OF HUMAN CAPITAL

This chart illustrates typical human capital curves as developed over a decade ago by Dorothy P. Rice and recently updated to reflect current experience[1]. The value obtained from these curves for any particular year of an average person's life represents the discounted value. Thus, if that sum were invested in an interest-bearing savings account, withdrawals equal to the average salary could be made for the years which the deceased would have lived. The total money thus withdrawn from the account would yield far more than the amount deposited (the amount of the value at the age on the curve).

---

[1] The Economic Cost of Illness Revisited. Barbara S. Cooper and Dorothy P. Rice. Social Security Administration, Office of Research and Statistics, 1975.

VALUE OF HUMAN CAPITAL

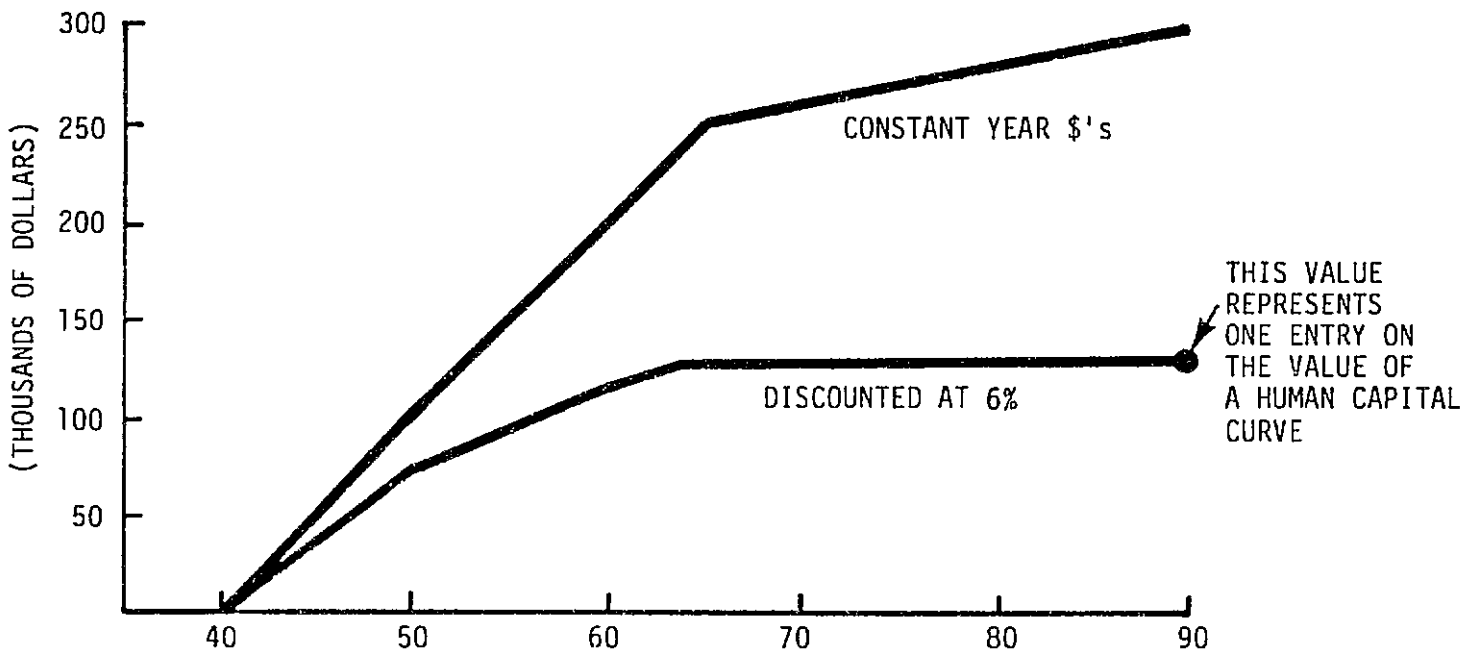


SAMPLE CALCULATION FOR VALUE OF HUMAN CAPITAL

In order to better understand the present value of future earnings, this simplified example is provided. The example assumes a white male, age 40 is earning $10,000 per year until age 65 and then his value would be $1,000 per year keeping house. We assume here that he suddenly loses his life and we want to plot his potential future earnings if he had not died. The cumulative and the discounted value of those earnings is shown. The discounted value assumes a six percent discount rate and the earnings are discounted back to age 40. The cumulative discounted value at the end of the curve (age 90) would be one point (at age 40 - white male) on the discounted life earnings curve if actual income figures had been used in this example.

SAMPLE CALCULATIONS FOR VALUE OF HUMAN CAPITAL

ASSUMED: WHITE MALE, AGED 40, INCOME $10,000/YR
UNTIL AGE 65, THEN $1000/YR (HOUSEKEEPING VALUE)*



*Note that the incomes used in this sample calaculation are illustrative. For this reason, the numerical results obtained differ slightly from the actual figures in the Value of Human Capital Curve.

MODIFIED VALUE OF HUMAN CAPITAL

ECON has selected the Value of Human Capital technique for the purpose of quantifying social benefits. This choice was made based on the wide acceptance by the medical economic community and the availability of well-documented data to produce such tables and life-value curves. To modify the curves we have obtained average-earnings data from the Department of Labor, and we have made minor modifications to remove some sex and race bias. In all other respects the technique remains intact.

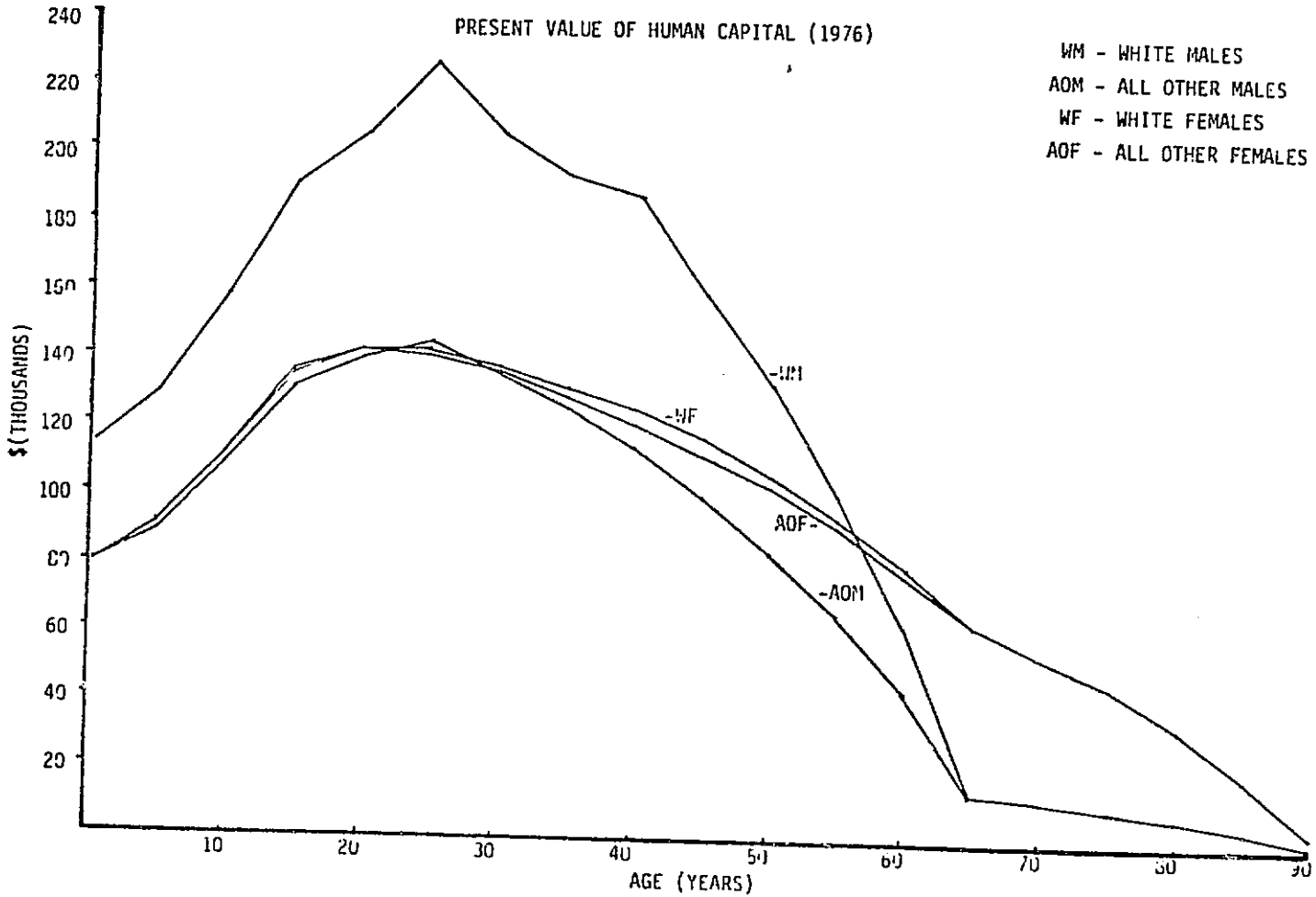
MODIFIED VALUE OF HUMAN CAPITAL

TO QUANTIFY SOCIAL BENEFITS THE VALUE OF HUMAN CAPITAL TECHNIQUE HAS BEEN SLIGHTLY MODIFIED TO REDUCE SEX AND RACE BIAS

- WIDELY UTILIZED
- PROVIDES GOOD BASELINE
- DATA AVAILABLE AND WELL DOCUMENTED

PRESENT VALUE OF HUMAN CAPITAL (1976)

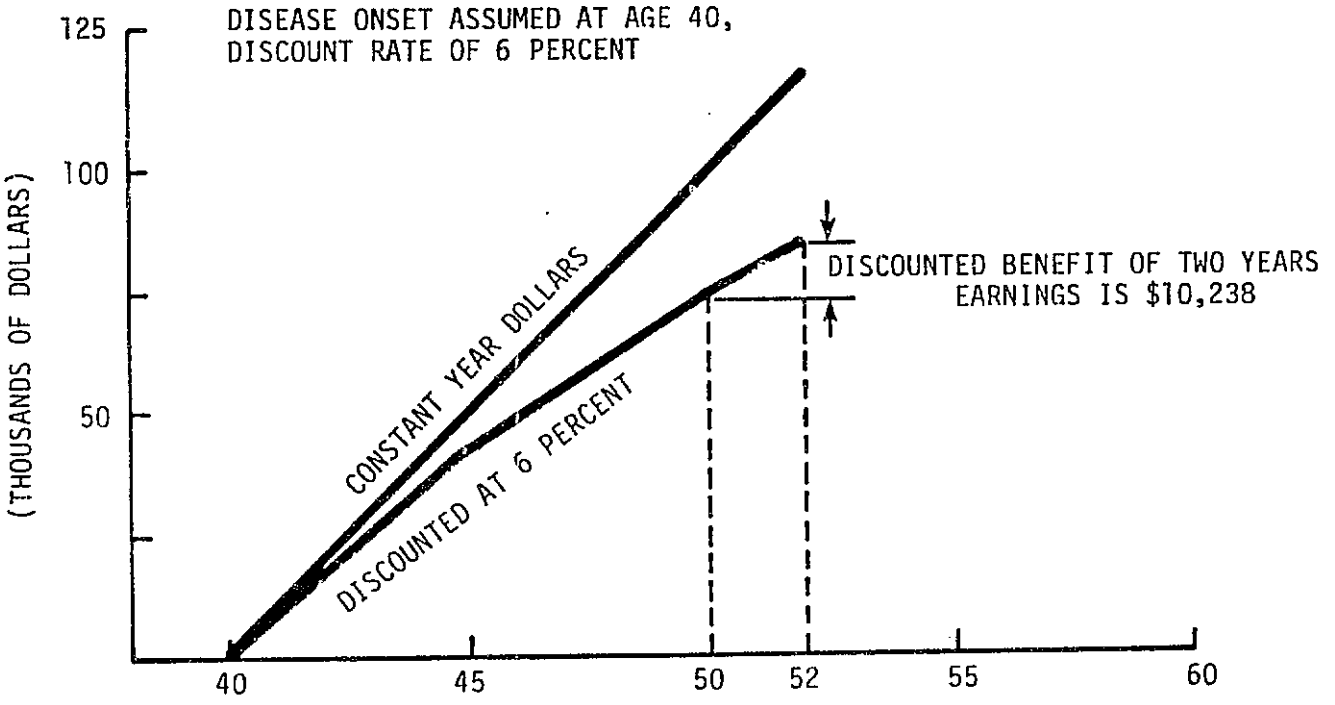
This slide represents the life-value curves developed by ECON utilizing the Value of Human Capital approach. This technique will be utilized to compute the value of extending life for a specified period. The procedures and assumptions used to prepare these revised curves are described in Appendix A.


PRESENT VALUE OF HUMAN CAPITAL (1976)
WM - WHITE MALES
AOM - ALL OTHER MALES
WF - WHITE FEMALES
AOF - ALL OTHER FEMALES
$(THOUSANDS)
240
220
200
180
160
140
120
100
80
60
40
20
-WM
-WF
-AOF
-AOM
10
20
30
40
50
60
70
80
90
AGE (YEARS)

SAMPLE CALCULATION FOR THE BENEFIT OF EXTENDING LIFE TWO YEARS

The example on page 48 illustrates the technique utilized to determine the present value of future earnings out to age 90. Now let us take an example that is more similar to the situation encountered in this study, namely the benefit of postponing death for N years. In the example, we have the same white male earning $10,000 per year and afflicted with a disease at age 40. With present treatment, his average life expectancy is 10 years but with the new treatment his life-expectancy is increased to 12 years. This technique is used in this study for determining the value of extending lives, but a 6 percent discount factor is utilized and actual earnings data from the Department of Labor. In the example the social benefit is calculated as the discounted value of the two additional years of earnings ($10,238). This method has been used in this study in order to quantify the social benefit of life extension. Actual earnings data from the Department of Labor and a 6 percent rate of discount have been used in this study.

SAMPLE CALCULATION FOR THE BENEFIT OF EXTENDING LIFE TWO YEARS



BENEFITS OF LYMPHOCYTE SUBGROUP SEPARATION AND CLASSIFICATION FOR TREATMENT OF END STAGE RENAL DISEASE AND BENEFITS OF THE SEPARATION OF UROKINASE PRODUCING CELLS FOR TREATMENT OF PULMONARY EMBOLISMS

BACKGROUND

BACKGROUND

In a previous study for NASA Headquarters, two promising candidate substances for space bioprocessing were selected for benefit evaluations.[1] These two substances were lymphocytes and urokinase. In the case of lymphocytes, ground-based research has led to the classification of two subgroups, and the objective of the space-based research is to further separate and extend the classification process within the two presently identified subgroups. At the present time, using ground-based techniques, urokinase-producing cells cannot be separated from other kidney cells. In both instances, electrophoretic separation in space has been proposed as the mechanism to effect separation. The clinical application selected for study in connection with lymphocyte subgroup classification, is the matching of donors and recipients for kidney transplantation; while the application selected for urokinase is the reduction of blood clots associated with thromboembolic diseases, specifically pulmonary embolisms. The referenced previous study contains a complete description of these two diseases and treatment systems, which is not repeated in this report for the sake of brevity. While other possible applications exist for these two substances, these two applications represent areas where immediate progress could be made if the space-based research is successful.

This previous study concluded that very large economic benefits could result from successful lymphocyte subgroup separation. During this study, it was also determined that it is possible that urokinase production costs could be reduced as a result of the successful separation of urokinase-producing cells, thus leading to increased availability and widespread use of urokinase in the treatment of thromboembolic diseases. This, in turn, could lead to a reduction in the number of deaths from pulmonary embolisms, and could possibly reduce the need for some surgical procedures and thus reduce the length of hospital stay.

In the present study the disease therapy system models for these two applications were reviewed, and the results extended to include both economic and social benefits.

---

[1] Preliminary Benefit Analysis of Biological Space Processing. ECON, Inc, 1 Sepetmber 1976.

BACKGROUND

- PREVIOUS STUDY OF LYMPHOCYTE SUBGROUP SEPARATION AND SEPARATION OF UROKINASE-PRODUCING CELLS USED A TRANSITIONAL PROBABILITY TECHNIQUE TO ESTIMATE ECONOMIC BENEFITS

SUBSTANCE	LYMPHOCYTES	UROKINASE
SPACE PROCESS	SEPARATE AND CLASSIFY SUBGROUPS	SEPARATE AND CONCENTRATE UROKINASE-PRODUCING CELLS
MECHANISM	ELECTROPHORISIS	ELECTROPHORISIS
CLINICAL APPLICATION	KIDNEY TRANSPLANTATION	THROMBOEMBOLIC DISEASES
CLINICAL IMPACT	IMPROVE TRANSPLANT ACCEPTANCE	LYSE BLOOD CLOTS

MORE DEFINITIVE DATA COLLECTED

To improve the reliability and accuracy of the model results in this study, additional data were collected about the treatment, costs and mortality rates of end stage renal disease (impacted by lymphocyte separation) and pulmonary embolisms (impacted by urokinase).

MORE DEFINITIVE DATA COLLECTED

TO IMPROVE THE BENEFIT ESTIMATION, DATA WAS COLLECTED RELATIVE TO:

- END STAGE RENAL DISEASE (ESRD)
  - + TREATMENT
  - + COSTS
  - + MORTALITY
- PULMONARY EMBOLISMS
  - + TREATMENT
  - + COSTS
  - + MORTALITY

END STAGE RENAL DISEASE

MODEL OF KIDNEY DISEASE

The treatments for end stage renal disease (ESRD) known today are dialysis and transplant. It is believed that through lymphocyte separation in space, a better understanding of the body's immunological systems will come about, resulting in better tissue matching and hence, a greater success rate in transplant operations.

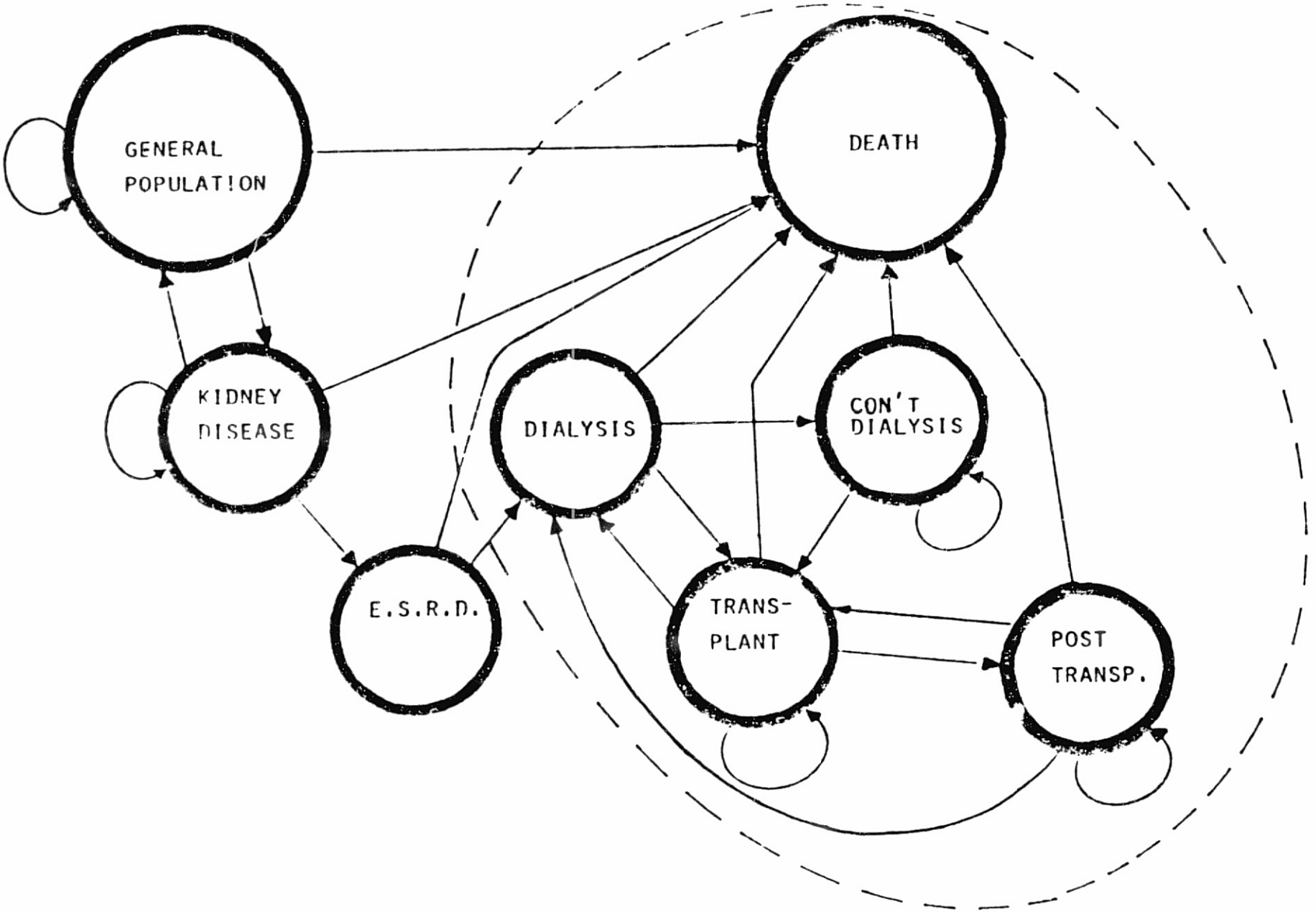
Eight states are defined in the model of kidney disease. Note that all five states encircled are reached after contraction of ESRD. These five states were singled out for the model thereby ignoring healthy people and those who had kidney disease, but not ESRD. We defined a discrete Markov Process for these five states, dictating that each year a transition would occur. The transition could result in movement from one state to the next or possibly in no movement at all.

Statistics were collected to enable the estimation of the potential benefits of space processing of lymphocyte separation. Three cases were defined with which to exercise the model: (1) current status, (2) partial improvement due to space processing, and (3) optimistic improvement due to space processing.

Among the statistics we collected for each case were:

1. How long did the patient live after contracting ESRD?
2. How many years after contracting ESRD did the patient enter each state?
3. How many years did the patient "reside" in each state?
4. Cost to public sector.
5. Cost to private sector.

MODEL OF KIDNEY DISEASE



ESRD DATA COLLECTION

Recent data was obtained enumerating the number of patients undergoing dialysis and the number receiving transplants. The data indicate that ECON had properly modeled the treatment regimes for ESRD in our previous study for NASA Headquarters.[1] Additionally, only minor modification was necessary to the cost data. The cost data used in this study for treatment of ESRD is shown in Appendix B.

[1] Preliminary Benefit Analysis of Biological Space Processing. ECON, Inc., 1 September 1976.

ESRD DATA COLLECTION

- LATEST KIDNEY TRANSPLANT STATISTICS OBTAINED
- MOST RECENT COUNT OF ESRD PATIENTS ON DIALYSIS OBTAINED
- COST DATA PREVIOUSLY OBTAINED APPEARS ADEQUATE
- ARTICLE REGARDING LONG-TERM TRANSPLANTATION CALCULATIONS LOCATED

TRANSITIONAL PROBABILITIES FOR END STAGE RENAL DISEASE

Transitional probabilities can be conveniently represented through the use of a matrix. The matrix is arranged with the present states listed vertically on the left of the matrix and the states which can be entered horizontally across the top. Thus, by following the column across the matrix the probabilities can be seen for entering any other state. There are certain transitions that are not possible and those transition boxes are darkened on the matrix in the figures (or given a value of zero).

The transition probabilities for the treatment of ESRD were estimated through consultation with experts in kidney disease and kidney transplantation, and by literature review. The probabilities were estimated for two cases: a baseline case and an improvement case. The baseline case represents the present state-of-the-art for treatment of ESRD. The improvement case represents the expected improvement brought about by the use of space processing to separate and classify lymphocyte subgroups.

TRANSITION PROBABILITIES FOR END STAGE RENAL DISEASE

PROBABILITY MATRIX FOR BASELINE CASE

	1ST YEAR DIALYSIS	CON'T DIALYSIS	TRANSP.	POST TRANSP.	DEATH
1ST YEAR DIALYSIS		.7	.2		.1
CON'T DIALYSIS		.92	.02		.06
TRANSPLANT	.45		.03	.42	.10
POST TRANSPLANT	.125		.03	.82	.025
DEATH					1.0

SOURCE:
Probability transitions determined from analyzing the statistics on the number of persons contracting ESRD annually, the number receiving dialysis, the number receiving transplants and the estimates of the percent dying the first year of ESRD. Sources include:

- House of Representatives, Hearings Before the House Subcommittee on Oversight on Medicare's End-Stage Renal Disease Program, G.P.O., June 24 - July 30, 1975.
- National Dialysis Registry, National Institute of Arthritis and Metabolic Diseases, N.I.H., Bethesda, Maryland, October 1, 1975.
- Advisory Committee of the Renal Transplant Registry, The Twelfth Report of the Human Renal Transplant Registry, J.A.M.A., August 18, 1975.
- Rogosin Kidney Center, Annual Report, The New York Hospital - Cornell Medical Center, New York, New York 1975.

PROBABILITY MATRIX FOR IMPROVEMENT CASE

	1ST YEAR DIALYSIS	CON'T DIALYSIS	TRANSP.	POST TRANSP.	DEATH
1ST YEAR DIALYSIS		.45	.45		.10
CON'T DIALYSIS		.79	.15		.06
TRANSPLANT	.16		.02	.77	.05
POST TRANSPLANT	.05		.02	.91	.02
DEATH					1.0

SOURCE:
Probability transitions determined after detailed discussions with Rogosin Kidney Center medical staff and recognition of the maximum impact to be the 60% of rejection cases sited as caused by the bodies immunological response.

RESULTS OF ESRD TREATMENT SIMULATION

One thousand iterations were run for the probability transition matrices for ESRD utilizing a Monte Carlo simulation. The results of the simulation are shown in the opposite chart.

As the transplant rejection rate and the death rate decrease, the life expectancy of the average patient increases. The assumption was made that as the kidney transplant rejection rate decreases, more patients will elect that form of treatment and thus the probability of transitioning to the transplant state was increased in the improvement case. Through a reduced mortality for transpiant patients, and an increase in the number of patients choosing that treatment, the expected patient life after contracting ESRD was extended by more than three years in the improvement case. Because the costs to both the government and the individual are both less for the post-transplant state a reduced cost situation is encountered, even with the extended period of life.

RESULTS OF ESRD TREATMENT SIMULATION

	BASELINE	IMPROVEMENT
	MEAN	MEAN
"AGE" (A) AT DEATH	13.72	17.11
NUMBER OF YEARS IN:		
CONTINUING DIALYSIS	10.64	3.60
TRANSPLANT	0.55	1.55
POST-TRANSPLANT	1.14	10.20
COST TO PUBLIC SECTOR PER INDIVIDUAL OVER INDIVIDUAL'S LIFE (1985 DOLLARS)		
UNDISCOUNTED	408,969	185,631
DISCOUNTED AT 6%	196,690	106,804
COST TO PRIVATE SECTOR PER INDIVIDUAL (1985 DOLLARS)		
UNDISCOUNTED	226,807	201,801
DISCOUNTED AT 6%	110,046	98,379

(A) THROUGHOUT, "AGE" IS MEANT TO BE YEARS AFTER CONTRACTING ESRD

THROMBOEMBOLIC DISEASES

MODEL OF PULMONARY EMBOLISM

The current treatments of thromboembolic diseases, specifically pulmonary embolisms, are heparin therapy and surgery. Additionally, it is believed that the use of the drug urokinase will become an effective treatment regime once it receives FDA approval for use in the United States and is commercially available. It is anticipated that not only will urokinase lyse, or dissolve, clots of the lungs, but also have the same effect on clots in other parts of the body.

Ten states were defined for the treatment of pulmonary embolisms as shown in the opposite figure. For the simulation, all states were utilized except the state representing the general population.

Statistics were collected to enable a comparison of the costs of treatment of pulmonary embolisms pre and post introduction of urokinase. Two cases were defined: baseline and improvement. The baseline case represents the current state-of-the-art of treatment of pulmonary embolisms (without urokinase), while the improvement case represents the anticipated state-of-the-art after the introduction of urokinase as a therapy system.

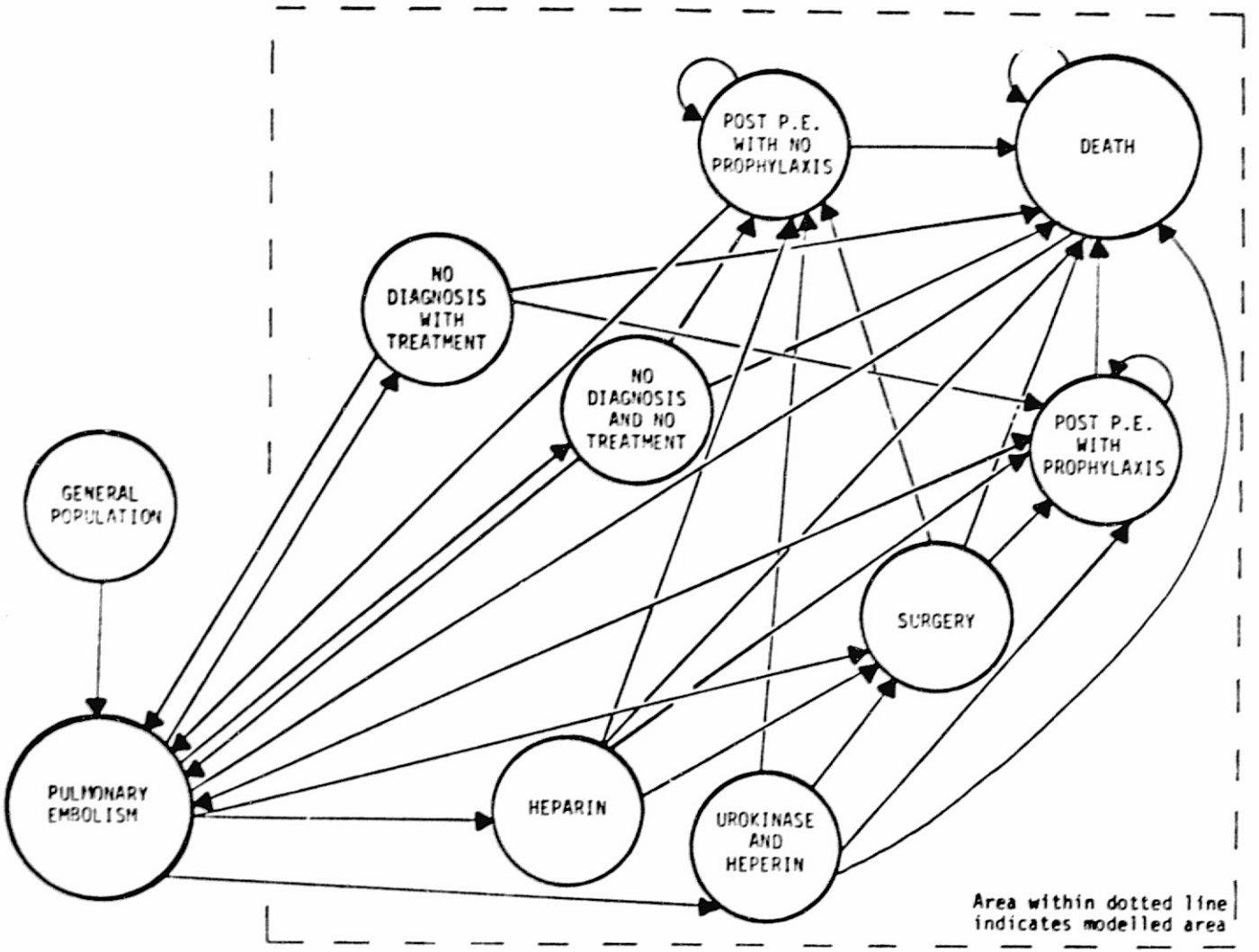
Among the statistics collected for each case were:

1. How long did the patient live after contracting pulmonary embolism?

2. How long did the patient "reside" in each state, particularly the post-treatment state which represents surgery?

3. Costs to the individual.

MODEL OF PULMONARY EMBOLISM



THROMBOEMBOLIC DISEASES DATA COLLECTION

The data-gathering effort provided a more refined and reliable estimate of life extension possible from the new health treatments made possible through space processing.

THROMBOEMBOLIC DISEASES DATA COLLECTION

- DATA ON THROMBOEMEBOLIC DISEASES BESIDES PULMONARY EMBOLISM OBTAINED
- BETTER DATA ON MORTALITY FROM PULMONARY EMBOLISM OBTAINED
- SOME DATA ON DOCTOR VISITS AND HOSPITAL STAYS OBTAINED
- IMPROVED DATA INPUTS WILL ALLOW MODEL TO GENERATE MORE ACCURATE ESTIMATES OF:
    - + YEARS OF LIFE EXTENDED
    - + REDUCED MORBIDITY

TRANSITION PROBABILITIES FOR TREATMENT OF PULMONARY EMBOLISMS

Transition probabilities were determined for the treatment of pulmonary embolisms through consulting with experts familiar with urokinase efficacy and by analyzing the literature on pulmonary embolisms. The sources of the transitional probabilities and the costs for treatment of pulmonary embolisms are shown in Appendix C. The transition probability matrices are given for the two cases as shown on the opposite page.

Cost estimates are based on actual experience in the case of a surgeon's fees, and on an approximation based on costs in other countries in the case of urokinase. The degree of severity of an embolism determines costs and the range is great. One patient may need surgery followed by intensive care while another patient may be treated medically, only to have to undergo surgery later.

TRANSITION PROBABILTIES FOR TREATMENT OF PULMONARY EMBOLISMS

BASELINE PULMONARY EMBOLISM CASE

	PULMONARY EMBOLISM	NO DIAGNOSIS WITH TREATMENT	NO DIAGNOSIS AND NO TREATMENT	POST P.E. WITH NO PROPHYLAXIS	HEPARIN TREATMENT	UROKINASE WITH HEPARIN TREATMENT	SURGERY	POST P.E. WITH PROPHYLAXIS	DEATH
PULMONARY EMBOLISM		.00	.63		.22	.00	.04		.11
NO DIAGNOSIS WITH TREATMENT	.00			.00					1.00
NO DIAGNOSIS AND NO TREATMENT	.01			.69					.30
POST P.E. WITH NO PROPHYLAXIS	.05			.94					.01
HEPARIN TREATMENT				.10			.04	.77	.09
UROKINASE WITH HEPARIN TREATMENT				.00			.00	.00	1.00
SURGERY				.05				.86	.09
POST P.E. WITH PROPHYLAXIS	.03							.96	.01
DEATH									1.00

IMPROVEMENT PULMONARY EMBOLISM CASE

	PULMONARY EMBOLISM	NO DIAGNOSIS WITH TREATMENT	NO DIAGNOSIS AND NO TREATMENT	POST P.E. WITH NO PROPHYLAXIS	HEPARIN TREATMENT	UROKINASE WITH HEPARIN TREATMENT	SURGERY	POST P.E. WITH PROPHYLAXIS	DEATH
PULMONARY EMBOLISM		.18	.44		.04	.21	.02		.11
NO DIAGNOSIS WITH TREATMENT	.01			.87					.12
NO DIAGNOSIS AND NO TREATMENT	.01			.69					.30
POST P.E. WITH NO PROPHYLAXIS	.05			.94					.01
HEPARIN TREATMENT				.10			.02	.79	.09
UROKINASE WITH HEPARIN TREATMENT				.05			.01	.90	.04
SURGERY				.05				.86	.09
POST P.E. WITH PROPHYLAXIS	.03							.96	.01
DEATH									1.00

RESULTS OF PULMONARY EMBOLISM TREATMENT SIMULATION

The probability matrices for pulmonary embolism were run utilizing a Monte Carlo simulation technique. The results of the runs are shown in the opposite chart.

The small increase in age at death of 1.56 years between the baseline and improvement cases is attributable to the fact that 11% of the pulmonary embolism cases result in immediate death, and that a very significant number of pulmonary embolisms are not diagnosed and do not receive treatment.[1]

---

[1] Natural History of Pulmonary Embolism. James E. Dalen and Joseph A. Alpert, "Progress in Cardiovascular Diseases", Volume XVII, No. 4, January-February 1975.

RESULTS OF PULMONARY EMBOLISM TREATMENT SIMULATION

MEASURE	BASELINE CASE	IMPROVEMENT CASE
	MEAN	MEAN
"AGE" (A) AT DEATH	20.33	21.89
NUMBER OF YEARS IN		
POST P.E. W/OUT PROPHYLAXIS	10.57	11.25
POST P.E. WITH PROPHYLAXIS	6.45	7.24
COST TO PRIVATE SECTOR PER INDIVIDUAL OVER INDIVIDUAL'S LIFE ($)		
UNDISCOUNTED	18,332	19,255
DISCOUNTED AT 6%	9,095	9,180

(A) THROUGHOUT "AGE" IS MEANT TO BE YEARS AFTER CONTRACTING P.E.

SUMMARY OF BENEFITS FOR TREATMENT OF

END STAGE RENAL DISEASE AND PULMONARY EMBOLISMS

SUMMARY OF BENEFITS OF TREATMENT FOR END STATE RENAL DISEASE AND PULMONARY EMBOLISMS

The ECON-developed medical treatment simulation model computes the expected life span of a patient contracting the disease in question and the expected costs to one average patient. It is estimated that there are 10,000 new ESRD patients each year and 750,000 cases of pulmonary embolism occur each year (whether diagnosed or not). The opposite table shows the benefits accruing to the group entering the disease state in one year. If no new treatment technique comes along, these benefits would accrue to those contracting the particular disease each successive year.

The computer program listing for the model of ESRD and pulmonary embolism treatment is given in Appendix D.

SUMMARY OF BENEFITS FOR TREATMENT OF END STAGE RENAL DISEASE AND PULMONARY EMBOLISMS

TYPE OF BENEFIT	BENEFITS TO DISEASE AS A RESULT OF NEW TREATMENT TECHNIQUES	
	PULMONARY EMBOLISM	END STAGE RENAL DISEASE
ECONOMIC (DECREASED COST FOR EQUAL CAPABILITY)	-$112.9 MILLION (OVER A 22 YEAR PERIOD) TO PEOPLE CONTRACTING P.E. DURING ONE YEAR (THIS COST COULD ALSO ACCRUE TO PEOPLE ENTERING THE SYSTEM EACH SUCCESSIVE YEAR)*	GOVERNMENT: $879.65 MILLION FOR THOSE ENTERING TREATMENT IN ONE YEAR (TAKES 17.11 YEARS TO REALIZE BENEFITS) PRIVATE: $96.73 MILLION FOR THOSE ENTERING TREATMENT DURING ONE YEAR (WOULD TAKE 17.11 YEARS TO REALIZE THE SAVINGS)
SOCIAL (EXTENDED MEAN LIFE EXPECTANCY ONCE DISEASE IS CONTRACTED)	AVERAGE CAPITALIZED VALUE OF EARNINGS FOR 1.56 YEARS FOR 750,000 PEOPLE IS $3.103 BILLION	ASSUMING THAT 50 PERCENT OF THOSE WHO WORKED CAN RETURN TO WORK THE CAPITALIZED VALUE OF 3.39 YEARS EARNINGS FOR 10,000 PEOPLE: $227 MILLION

*COST OF TREATMENT WITH UROKINASE EXCEEDS COST OF PRESENT TREATMENT

BENEFITS OF THE SEPARATION OF BETA CELLS FOR THE TREATMENT OF DIABETES

TYPES OF DIABETES MELLITUS

Generally speaking, there are two types of diabetes mellitus: adult-onset and juvenile-onset. Adult-onset diabetes is frequently and increasingly being controlled by diet manipulation and oral hypoglycemic techniques; these diabetics are typically not insulin-dependent. Juvenile-onset diabetics, on the other hand, typically are insulin-dependent and would benefit from any technologies which could improve insulin therapy, either the process of introduction of insulin into the body or the quality of the insulin itself.

TYPES OF DIABETES MELLITUS

- ADULT ONSET (INSULIN-INDEPENDENT)
  - + ONSET USUALLY AFTER 40
  - + GENERALLY CONTROLLED BY DIET AND/OR ORAL HYPOGLYCEMIC AGENTS
  - + HIGH INCIDENCE OF CORONARY COMPLICATIONS

- JUVENILE ONSET (INSULIN-DEPENDENT)
  - + ONSET USUALLY BEFORE 25 (90%)
  - + REQUIRES USE OF INSULIN
  - + HIGH INCIDENCE OF KIDNEY AND EYE COMPLICATIONS

DIABETIC PATIENT POPULATION OF THE UNITED STATES

Of the 1.24 millior insulin-dependent diabetics in the United States today 85 percent are thought to have had diabetes onset between 0 and 19 years of age, 5 percent between 20 and 39 years, 5 percent between 40 and 59 and 5 percent at age 60 or more.

Further, the population is:

33.0%	White Male
52.2%	White Female
5.7%	All Other Male
9.1%	All Other Female.

Source: Medical advisors and major statistical sources, see page 119.

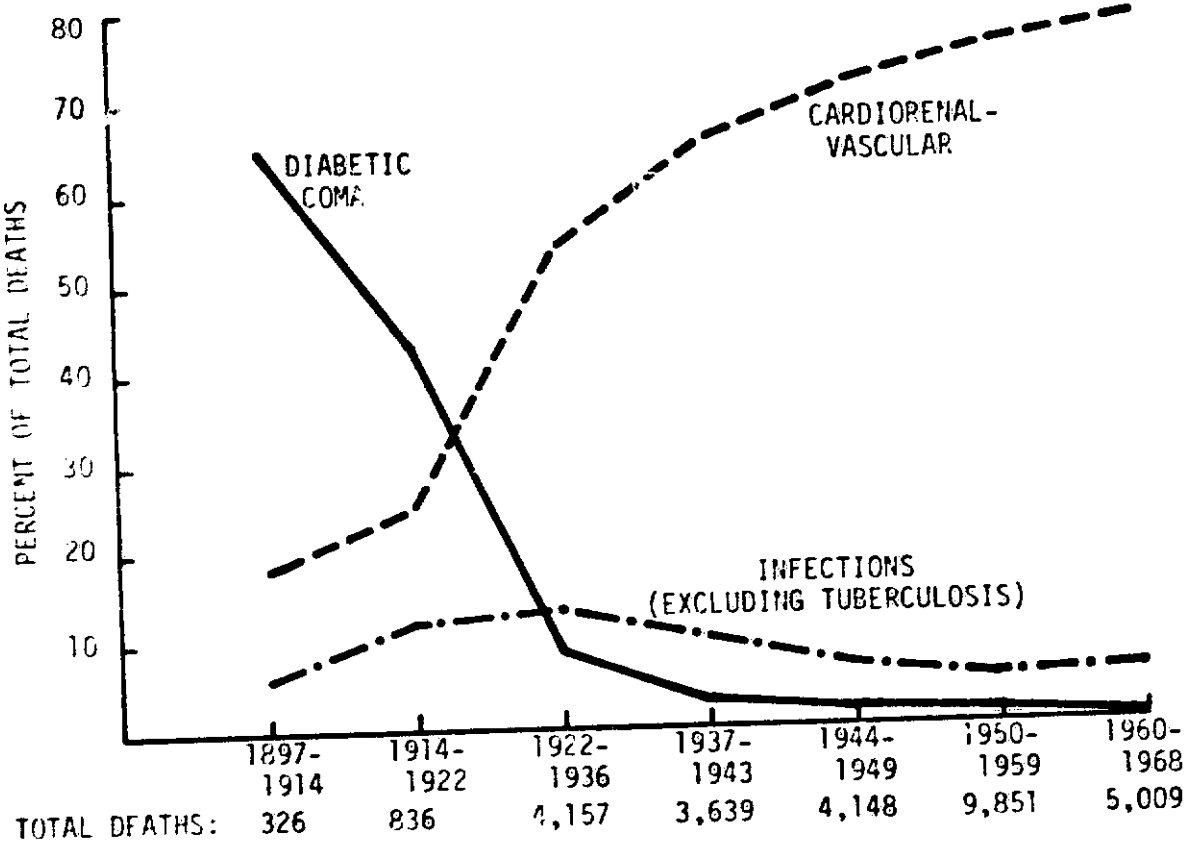
DIABETIC PATIENT POPULATION OF THE UNITED STATES

1.24 MILLION	INSULIN-DEPENDENT
1.25 MILLION	ORAL MEDICATION
3.50 MILLION	DIET CONTROLLED
4 MILLION	ESTIMATED UNDIAGNOSED

CAUSES OF DIABETIC DEATHS: 1897-1968

The rapid growth of insulin therapy in the early part of this century greatly decreased the incidence of diabetic coma. The problem of survival of the diabetic became not one of immediate complications (that is, coma), but of long-term complications. Juvenile-onset diabetics could be expected to function normally in society up to the point where the long-term complications, such as kidney, ocular and cardio-vascular, started to evidence later in life.

CAUSES OF DIABETIC DEATHS: 1897-1968



MAJOR COMPLICATIONS OF DIABETES

All of the major, known complications of diabetes were considered in this study. Several of these--neuropathy, ketosis, allergy and visual impairments other than diabetic retinopathy--were not explicitly modeled because their effects were not sufficiently significant, because not enough was known about the complication, or because it was felt that the improvements being studied would not impact the complication. The major complications--diabetic retinopathy, nephropathy, cardiovascular, peripheral vascular and insulin resistance--are all modeled in this study.

MAJOR COMPLICATIONS OF DIABETES

1.	DIABETIC RETINOPATHY	- MODELED
2.	OTHER VISUAL (GLAUCOMA, CATARACTS)	- EFFECTS NOT SIGNIFICANT
3.	NEPHROPATHY	- MODELED
4.	CARDIOVASCULAR	- MODELED
5.	NEUROPATHY	- INSUFFICIENT DATA
6.	PERIPHERAL VASCULAR	- MODELED
7.	KETOSIS	- NOT IMPACTABLE
8.	ALLERGIC REACTION	- EFFECTS NOT SIGNIFICANT
9.	INSULIN RESISTANCE	- MODELED

HYPOTHESES ABOUT DEVELOPMENT OF COMPLICATIONS IN DIABETICS

After consulting with medical contacts[1] and reviewing relevant medical literature, it was assumed for the modeling effort that 50 percent of all complications arose from imperfect control of blood sugar levels, 25 percent were due to antibody build up to foreign insulin and 25 percent to other unknown factors. These estimates reflect the degree of agreement among the expert medical community. That is, while virtually all physicians agree that complications arise from poor control of diabetes, fewer believe that antibody production or other unknown factors are significant causes. In most cases this lack of agreement takes the form of uncertainty rather than disagreement.

[1] See page 119 for list of medical advisors and major statistical sources.

HYPOTHESES ABOUT DEVELOPMENT OF COMPLICATONS IN DIABETICS

1. IMPERFECT CONTROL
2. ANTIBODIES OF FOREIGN (PORCINE, BOVINE) INSULIN
3. UNKNOWN FACTORS

ANIMAL INSULIN: EXPECTED CHANGES IN SUPPLY AND DEMAND

The supply of animal insulin is expected to become more expensive in the future. This is due to the fact that the removal of the pancreas from cattle and hog carcasses is labor intensive and meat packers are resisting the performance of this function. On the other hand, the incidence of diabetes in the United States is increasing at about 6 percent per year, thus creating greater demand pressures on the existing supply.

ANIMAL INSULIN: EXPECTED CHANGES IN SUPPLY AND DEMAND

- SUPPLY:

  + INCREASED COST OR REDUCTION IN PRODUCTION EXPECTED

- DEMAND

  + INCREASED DEMAND EXPECTED DUE TO RISE IN INCIDENCE OF DIABETES BY 6% PER YEAR

POSSIBLE TREATMENTS OF DIABETES

ECON modeled several possible treatments of diabetes, including the most commonly used now: injection of foreign insulin. The problem of build-up of antibodies could be overcome by the use of "human" insulin, taken directly from human pancreas, cultured from Beta cells extracted from human pancreas, synthesized, or produced from E. coli bacteria. Space bioprocessing can assist the extraction of insulin or Beta cells from the human pancreas by providing a superior environment for electrophoresis. Either foreign or human insulin can be used in combination with an implanted device known as an artificial pancreas which monitors the insulin level in the body and secretes insulin as necessary on a continual basis. The extraction of Beta cells from the human pancreas offers the possibility that these cells can be injected into and accepted by a diabetic patient. If successfully accomplished, this could eliminate the problem of diabetes. In extreme cases, pancreas transplants may be warranted; this would not be a primary form of treatment, however, because the survival rate of such transplant patients is extremely low. Other forms of treatment, such as hormone control, were not modeled either due to insufficient information or because they were not directly pertinent to the subject of this study.

POSSIBLE TREATMENTS OF DIABETES

CONVENTIONAL	-	INJECTION OF FOREIGN (BOVINE, PORCINE) INSULIN
*HUMAN INSULIN	-	FROM CULTURED BETA CELLS SYNTHESIS OR E. COLI
ARTIFICIAL PANCREAS	-	MONITORING AND SECRETING FOREIGN INSULIN
*ARTIFICIAL PANCREAS	-	MONITORING AND SECRETING HUMAN INSULIN
*BETA-CELL TRANSPLANT	-	TRANSPLANT OF SEPARATED INSULIN-PRODUCING CELLS
PANCREAS TRANSPLANT	-	DUE TO COMPLEXITY AND LIMITED SUCCESS MODELED ONLY AS A TREATMENT FOR MULTIPLE COMPLICATIONS
OTHER HORMONE CONTROL	-	NOT MODELED DUE TO INSUFFICIENT INFORMATION

*POTENTIALLY IMPACTABLE BY SPACE BIOPROCESSING

TIME TO ASSESS SUCCESS OF TREATMENT

Even if human insulin and artificial pancreas techniques are developed, the actual proof of their success will require many years of evaluation. This is because we are dealing with long-run complications. The effects of treatment begun now on a juvenile diabetic cannot be assessed on average for at least twenty years.

TIME TO ASSESS SUCCESS OF TREA MENT

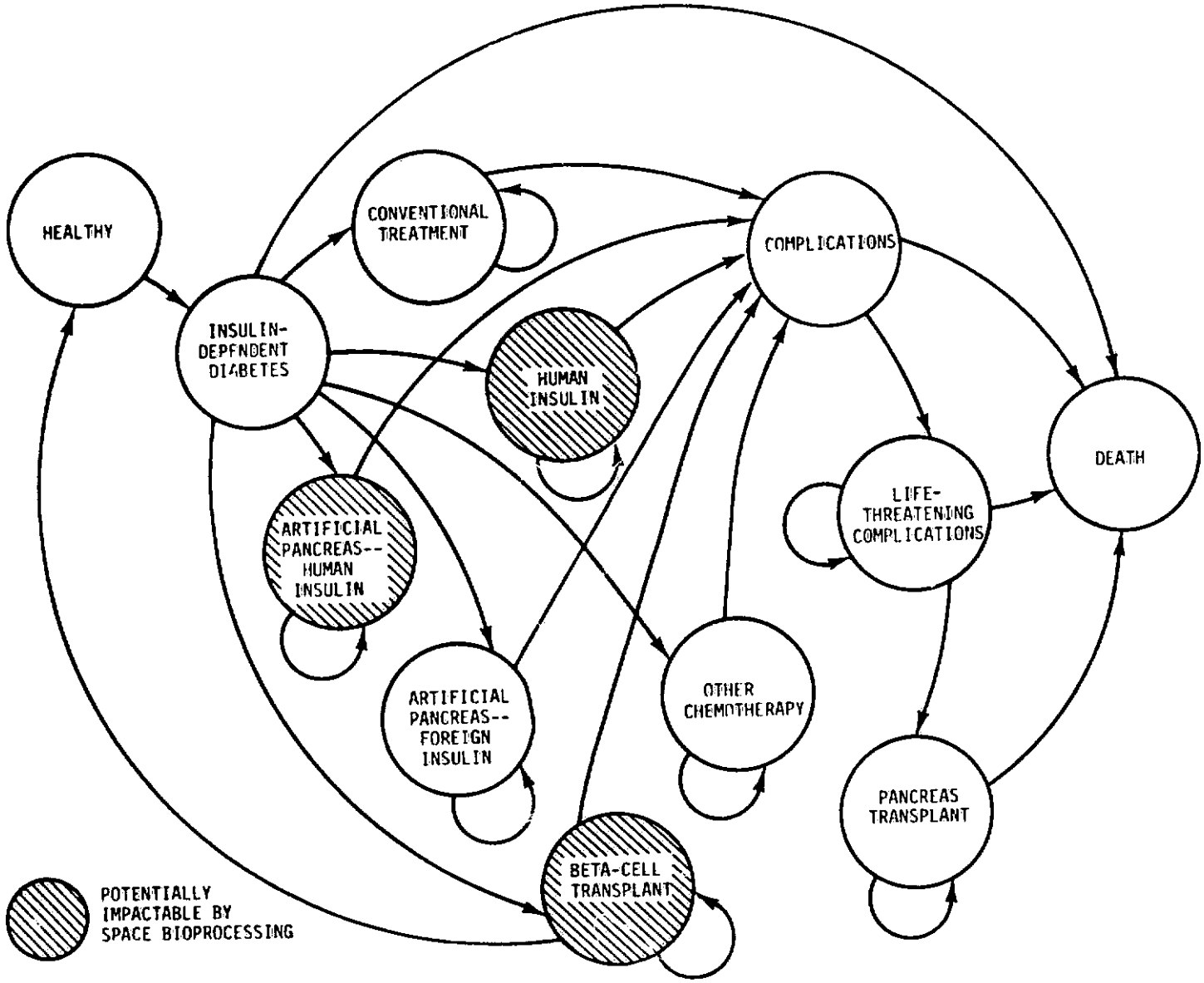
- HUMAN INSULIN--MINIMUM OF 10 TO 20 YEARS REQUIRED
- BETA CELL TRANSPLANT OR ARTIFICIAL PANCREAS MAY REQUIRE LESS TIME

BETA CELLS ISLETS OF THE LANGERHANS--SIMPLIFIED ILLUSTRATION OF THE DISEASE THERAPY MODEL

As a simplified illustration of the model, a healthy person can be found to have insulin-dependent diabetes. He then acquires some form of treatment and stays with that treatment (unless he has a successful Beta cell transplant in which case he is "cured") until he either dies or develops some complication. The complication persists (generally diabetic complications are not curable) until the patient dies or enters a state of severe, or life-threatening, complications. At this point a pancreas transplant is considered if it is deemed likely that the patient's life can be extended. The terminal state is, of course, death. Although not shown, the patient continues with the same diabetic therapy throughout his life (unless he has a successful Beta-cell transplant). Our model assumes steady state conditions, dealing with new patient population. Because of the steady state nature of the model we assume that once a patient enters a given treatment regime that he remains in that regime for the remainder of his life. The best available treatment at the time of onset will always be selected.

The model is employed to assess how a form of treatment, if available, compares to the other available treatments.

BETA CELLS ISLETS OF THE LANGERHANS--SIMPLIFIED ILLUSTRATION OF THE DISEASE THERAPY MODEL

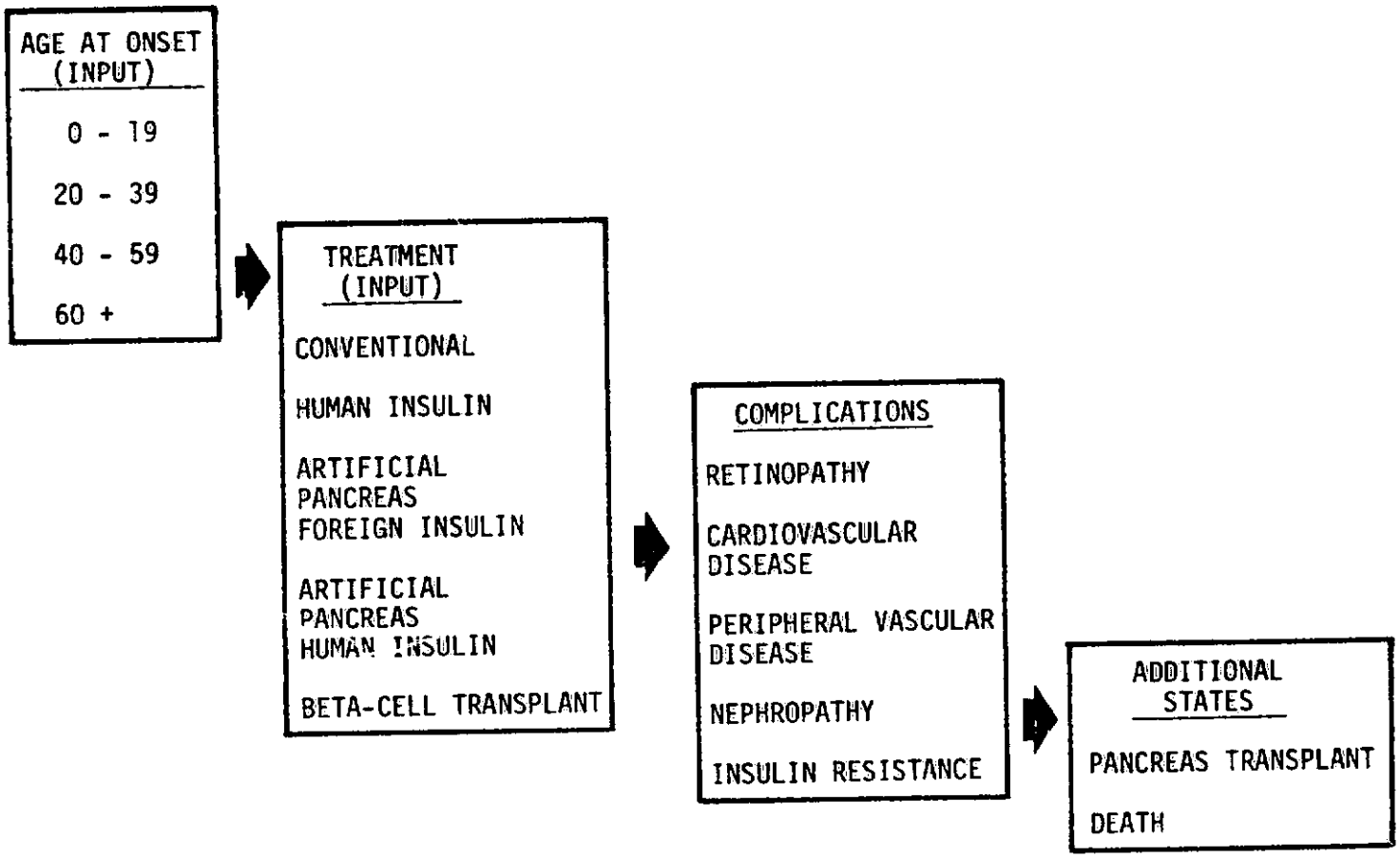


DIABETES TRANSITIONAL PROBABILITY MODEL

The transitional probability model performs as follows: an insulin-dependent patient is selected from among the four age-of-onset classes shown. A treatment is selected and the individual's progression through life is simulated. At any point in time (time is incremented in five-year steps) the individual has a specified probability of contracting any of the complications modeled, or of dying. Any or all complications can be contracted before death. If the individual has several complications, yet is young enough to warrant a pancreas transplant this is an additional possible state before death. The model works iteratively, selecting many patients from each age-of-onset class.

The program listing for this model is contained in Appendix E.

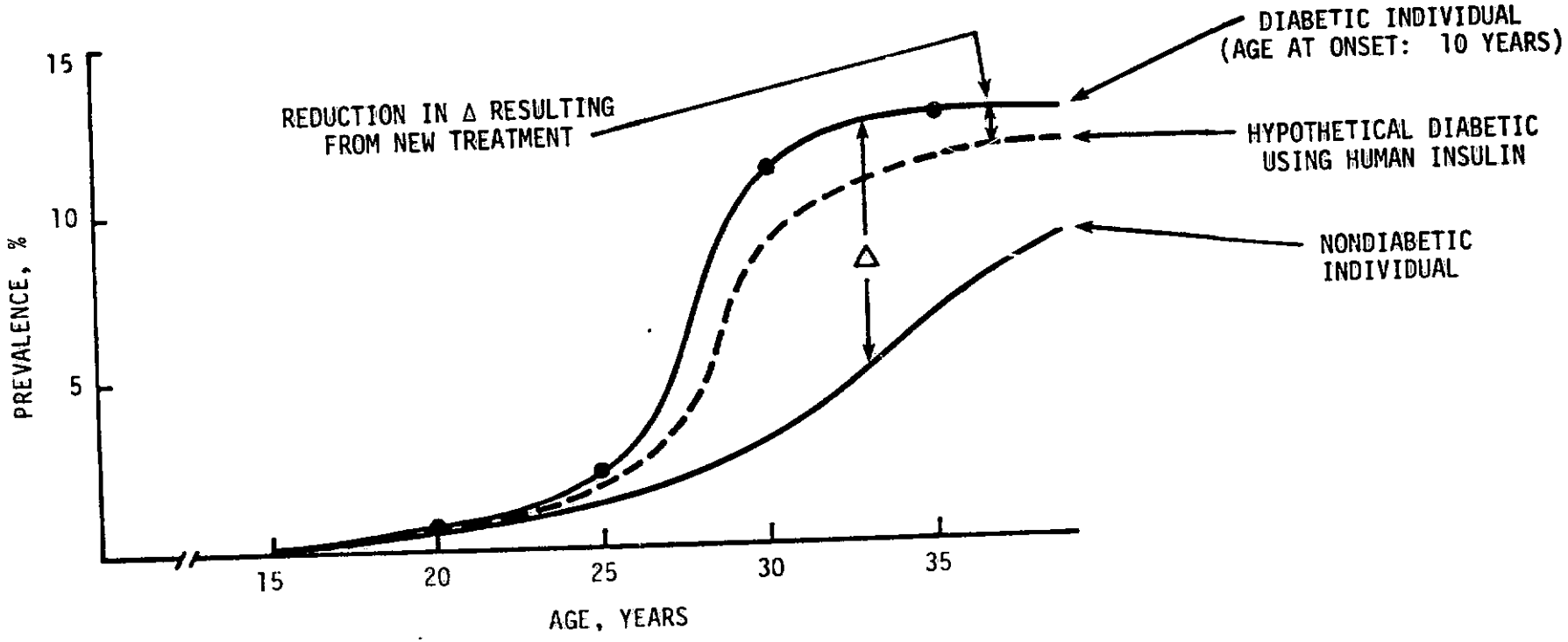
DIABETES TRANSITIONAL PROBABILITY MODEL



PREVALENCE OF CARDIOVASCULAR COMPLICATIONS AMONG DIABETICS AND GENERAL POPULATION

Improvements due to superior therapy reduce the incidence of any particular complication among the diabetic population. Improvements beyond the typical, nondiabetic individual are not considered. The difference in the prevalence of any complication between the diabetic under conventional treatment and the nondiabetic is shown as Δ in the opposite figure. This distance is assumed to be reduced by different amounts (by 25 percent for the dashed line shown) according to the treatment type and the complication involved.

PREVALENCE OF CARDIOVASCULAR COMPLICATIONS
AMONG DIABETICS AND GENERAL POPULATION



ASSUMED IMPROVEMENTS DUE TO IMPROVED TREATMENTS IN PREVALENCE OF DIABETIC COMPLICATIONS

The introduction of the treatment of diabetes with human insulin will reduce the complications of diabetes by alleviating the problem of the production of antibodies to foreign insulin and perhaps by providing better control of blood sugar levels. The chart presented here shows the expected reduction of prevalence of complications in the diabetic population relative to the normal population, the Δ from the previous figure. This is not the same as reducing the absolute prevalence of complications by the given percent in that the complicating diseases do occur in the general population and it is not expected that through the use of human insulin or any other treatment of diabetes, diabetic prevalence could be reduced below the level encountered in the general population. Because of the uncertainty in the medical profession as to the cause of diabetic complications, two estimates of the possible reductions, "optimistic" and more "realistic" reductions, have been assigned for human insulin treatment.

The treatment of diabetes with a Beta cell transplant is assumed to reduce the prevalence of complicating diseases to the level observed in the normal population.

In either case, since insulin resistance is seen to be totally the result to antibody binding with the use of foreign insulin, this complication would be eliminated.

ASSUMED IMPROVEMENTS IN PREVALENCE OF DIABETIC COMPLICATIONS
DUE TO IMPROVED TREATMENTS

PERCENTAGE REDUCTION IN Δ (SEE PAGE 111)

	HUMAN INSULIN		ARTIFICIAL PANCREAS-- FOREIGN INSULIN	ARTIFICIAL PANCREAS-- HUMAN INSULIN		BETA CELL
	OPTIMISTIC	REALISTIC		OPTIMISTIC	REALISTIC	
DIABETIC RETINOPATHY	25	17.5	50	75	62.5	100
CARDIOVASCULAR	25	12.5	50	75	62.5	100
NEPHROPATHY	50	25	25	75	50	100
PERIPHERAL VASCULAR	25	12.5	50	75	62.5	100
INSULIN RESISTANCE	100	100	0	100	100	100

The age at onset of the individual as well as the best available treatment are selected and input into the model. The model contains probabilities of moving from any state to another as a function of time. Costs of treatment and costs of complications (direct and indirect) are calculated as the individual progresses. The costs of death based on the amount of productive lifetime foregone are also included. For each patient the total costs are calculated and averaged across individuals and age-of-onset classes to obtain an estimate of the costs of diabetes associated with each type of treatment.

DIABETES MODEL

- INPUT REQUIREMENTS
  - + AGE OF PATIENT AT ONSET OF DIABETES
  - + TREATMENT TYPE
- INCORPORATED IN MODEL
  - + INCIDENCE OF COMPLICATIONS BY AGE AT ONSET AND DURATION OF DIABETES
  - + COSTS OF TREATMENT BY TYPE
  - + DIRECT AND INDIRECT COST OF TREATING DIABETES AND ITS COMPLICATIONS
  - + MORTALITY RATES BY COMPLICATION AND ASSOCIATED COSTS
  - + EXPECTED IMPROVEMENT IN MORTALITY AND MORBIDITY DUE TO TREATMENT TYPES

THE ASSUMPTIONS

The important assumptions embedded in the transitional probability model are listed here.

THE ASSUMPTIONS

- THERE IS NO POSSIBILITY OF CHANGING FROM ONE TYPE OF TREATMENT TO ANOTHER; IT IT ASSUMED THAT ONCE A TREATMENT IS SELECTED, THE PATIENT WILL FOLLOW THE SAME TREATMENT UNTIL DEATH
- THE HUMAN CAPITAL APPROACH TO THE VALUE OF EXTENDING PRODUCTIVE LIFE IS ASSUMED
- COSTS, BOTH DIRECT AND INDIRECT, ARE DISCOUNTED AT 6 PERCENT TO OBTAIN PRESENT VALUE
- BENEFITS ARE INFLATED AT A CONSTANT RATE OF 6 PERCENT TO 1985, THE ASSUMED FIRST YEAR OF TREATMENT BENEFITS
- 50 PERCENT OF COMPLICATIONS ARISE DUE TO IMPERFECT CONTROL OF BLOOD SUGAR LEVELS, 25 PERCENT TO ANTIBODY BUILD-UP AGAINST FOREIGN INSULIN, AND 25 PERCENT TO OTHER UNKNOWN FACTORS
- COSTS OF TREATMENTS AND COMPLICATIONS ARE SHOWN IN APPENDICES F AND G
- 25 PERCENT OF THOSE PATIENTS WITH THREE COMPLICATIONS UNDER 60 YEARS OF AGE RECEIVE PANCREAS TRANSPLANT, 35 PERCENT OF THOSE UNDER 60 YEARS WITH FOUR OR MORE COMPLICATIONS RECEIVE PANCREAS TRANSPLANT
- 70 PERCENT OF THOSE RECEIVING A PANCREAS TRANSPLANT DIE WITHIN THE FIRST FIVE-YEAR PERIOD, THE REMAINDER DIE IN THE NEXT FIVE-YEAR PERIOD

MAJOR DATA SOURCES

The major sources of information for the model formulation and description of the diabetic population are listed here.

MAJOR DATA SOURCES

- INFORMATION SOURCES

  C.J. VAN OSS - STATE UNIVERSITY OF NEW YORK

  M. MACGILLIVRAY - BUFFALO CHILDRENS HOSPITAL

  W. CHICK - JOSLIN CLINIC

  D. MARTIN - MASSACHUSETTS GENERAL HOSPITAL

  J.S. NAJARIAN - UNIVERSITY OF MINNESOTA

- STATISTICAL SOURCES

  REPORT OF THE NATIONAL COMMISSION ON DIABETES TO THE CONGRESS OF THE UNITED STATES, NATIONAL INSTITUTES OF HEALTH

  DIABETES MELLITUS, NATIONAL INSTITUTES OF HEALTH

  DIABETES SOURCE BOOK, U.S. PUBLIC HEALTH SERVICE

  MORBIDITY AND MORTALITY IN DIABETICS IN THE FARMINGTON POPULATION SIXTEEN YEAR FOLLOW-UP STUDY, GARCIA, ET.AL.

  JOSLIN'S DIABETES MELLITUS, MARBLE, ET AL.

  CHANGES IN THE COSTS OF TREATMENT OF SELECTED ILLNESSES, SCITOVSKY AND MCCALL

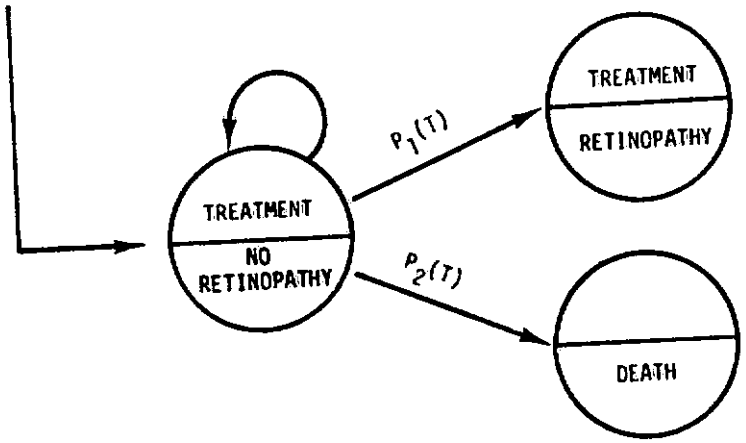
  THE ECONOMIC COST OF ILLNESS REVISITED, COOPER AND RICE

TRANSITION PROBABILITY TABLE FOR CONVENTIONAL TREATMENT FOR RETINOPATHY

For each complication, the probability of incidence, $P_1(T)$, (assuming that the complication was not present in the last time interval) is specified as a function of age onset and duration of diabetes. A separate probability transition table exists for each type of treatment, as well as each complication. The probability of dying, $P_2(T)$, is similarly modeled as a function of the number of complications present as well.

TRANSITION PROBABILITY TABLE FOR CONVENTIONAL TREATMENT FOR RETINOPATHY

AGE AT ONSET	DURATION OF DIABETES (YEARS)				
	5	10	15	20	25+
0-19	0.00	0.07	0.16	0.21	0.47
20-39	0.03	0.07	0.22	0.36	0.07
40-59	0.04	0.22	0.13	0.23	0.24
60+	0.11	0.15	0.07	0.06	0.10



STATISTICAL DATA SOURCES FOR TRANSITIONAL PROBABILITY MATRICES OF CONVENTIONAL TREATMENT

The literature on diabetic complications was thoroughly searched in order to obtain data for the transition probability tables. A list of the primary data sources is presented.

STATISTICAL DATA SOURCES FOR TRANSITIONAL PROBABILITY MATRICES OF CONVENTIONAL TREATMENT

Retinopathy

Diabetes and Its Management, W. G. Oakley, D. A. Pyke and K. W. Taylor, Blackwell Scientific Publications, London, 1973.

Proteinuria (Nephropathy)

"The Kidney and Renal Tract," J. S. Cameron, J. T. Ireland and P. J. Walters in Complications of Diabetes, H. Keen and J. Jarrett (Editors), Edward Arnold, London, 1975.

Coronary Artery Disease (Cardiovascular)

Diabetes and Its Management, Oakley et al.

"Differences in Cardiovascular Morbidity and Mortality Between Previously Known and Newly Diagnosed Adult Diabetics," J. B. Herman, J. H. Medalies and U. Goldbourt, Diabetologia 13, 229-234, 1977.

Peripheral Vascular

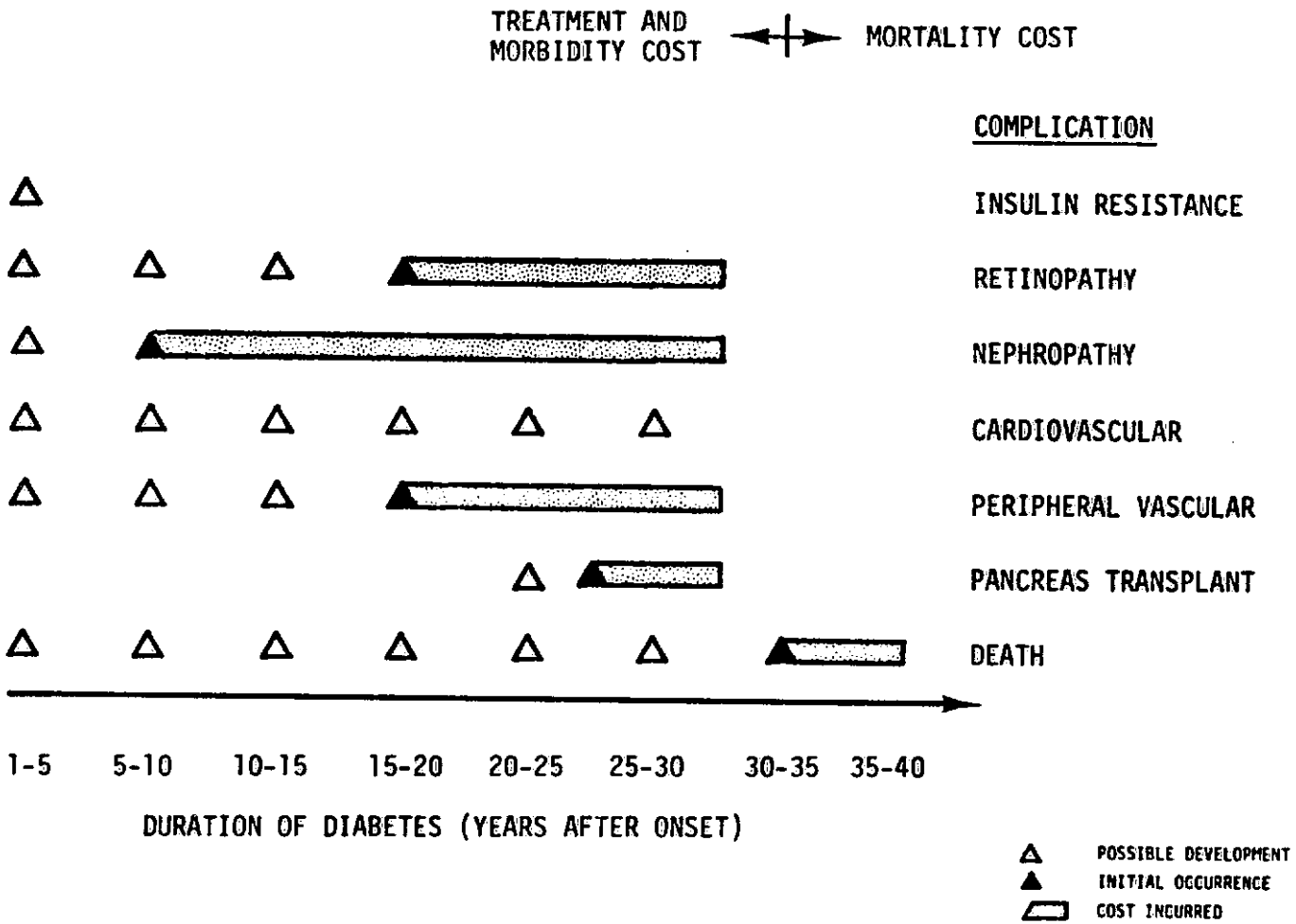
Report of the National Commission on Diabetes, Volume III, Part 2, "Scope and Import of Diabetes (II)," DHEW, 1976.

EXAMPLE OF THE OPERATION OF THE DIABETES TRANSITIONAL PROBABILITY MODEL

Consider some individual patient from one of the classes of age-of-onset. During each period of time, he has a specified chance of contracting each of the complications--unless he already has the complication, in which case he keeps it until death. The costs of treatment as well as the morbidity costs (e.g., absence from work or inability to work) are calculated period by period. At some point the individual dies, at which time a mortality cost, which is the income foregone for the remainder of the expected lifetime of the nondiabetic individual, is added. All costs are appropriately discounted (6 percent is used as the discount rate) and summed to obtain a present value cost associated with that patient.

The sample patient shown opposite incurs no complications in the first five-year period, but is afflicted with nephropathy in the second five-year interval. In the next interval, no new complication evidences although nephropathy persists. In the fourth period, the sample patient is afflicted with both retinopathy and peripheral vascular complications. All complications incurred persist and in the sixth period a pancreas transplant is performed. The patient dies in the following period.

EXAMPLE OF THE OPERATION OF THE DIABETES TRANSITIONAL PROBABILITY MODEL



Costs of treatment in 1976 dollars are presented for the initial five years after onset and for each five-year period following. Three cost levels (#1, #2, #3) are given for the costs of obtaining human insulin since more specific information is not available at this time. Appendix F presents these costs in considerable detail. The distinction between the "optimistic" and "realistic" cases refers not to cost distinctions but to the improvement in complications believed possible as discussed on page 112 of this report.

COST OF DIABETES TREATMENT

TREATMENT*	FIRST 5-YEAR PERIOD ($/PATIENT)	ADDITIONAL 5-YEAR PERIODS ($/PATIENT)
1. CONVENTIONAL	3080	2665
2. HUMAN INSULIN #1 OPTIMISTIC**	3080	2665
3. HUMAN INSULIN #1 REALISTIC	3080	2665
4. HUMAN INSULIN #2 OPTIMISTIC**	3630	3765
5. HUMAN INSULIN #2 REALISTIC	3630	3765
6. HUMAN INSULIN #3 OPTIMSITIC**	4318	5140
7. HUMAN INSULIN #3 REALISTIC	4318	5140
8. ARTIFICIAL PANCREAS/FOREIGN	22695	11075
9. ARTIFICIAL PANCREAS/HUMAN #1** OPTIMISTIC	22695	11075
10. ARTIFICIAL PANCREAS/HUMAN #1 REALISTIC	22695	11075
11. ARTIFICIAL PANCREAS/HUMAN #2** OPTIMISTIC	23355	12175
12. ARTIFICIAL PANCREAS/HUMAN #2 REALISTIC	23355	12175
13. ARTIFICIAL PANCREAS/HUMAN #3** OPTIMISTIC	24380	13550
14. ARTIFICIAL PANCREAS/HUMAN #3 REALISTIC	24380	13550
15. BETA-CELL TRANSPLANT	7092	618
PANCREAS TRANSPLANT	30098	25500

*COST OF DIABETIC TREATMENT

**SEE APPENDIX F FOR VARIATIONS IN COST OF HUMAN INSULIN, COST LEVELS #1, 2 AND 3

Similarly, the costs of each complication are presented. More detail is available in Appendix G.

COST OF DIABETIC COMPLICATIONS*

COMPLICATION	FIRST 5-YEAR PERIOD** ($/PATIENT)	ADDITIONAL 5-YEAR PERIODS** ($/PATIENT)
RETINOPATHY	$ 625	$ 1,250
CARDIOVASCULAR DISEASE	9,940	11,665
PERIPHERAL VASCULAR DISEASE	20,500	35,000
NEPHROPATHY	2,500	5,000
INSULIN RESISTANCE	14,433	12,685

*SEE APPENDIX G FOR COST BREAKDOWN AND SOURCES.

**COST OF TREATMENT AND MORBIDITY

PRESENT VALUE OF ECONOMIC AND SOCIAL COSTS BY TREATMENT FOR PRESENT DIABETIC POPULATION

If one were to consider the present diabetic population, one could use the model discussed herein to estimate the total costs attributable to diabetes in its present state. This is done in standard Monte Carlo fashion by running through the model many patients in each age-of-onset class and then averaging to find an average cost per patient for each class. This average is then multiplied by the number of patients in each class in the current patient population. These costs, summed across classes, are presented here for each treatment type. Economic costs are direct expenditures for treatment, both for diabetes and complications, while social costs refer to work days lost and reduced productive lifetime.

The dollar value represents 1985 dollars which are calculated from 1976 dollars using a 6 percent rate of inflation.

PRESENT VALUE OF ECONOMIC AND SOCIAL COSTS BY
TREATMENT FOR PRESENT DIABETIC POPULATION

		ECONOMIC COSTS (1985$, MILLIONS)		SOCIAL COSTS (1985$, MILLIONS)	TOTAL COSTS (1985$, MILLIONS)		
1.	CONVENTIONAL	34466.9		59112.3	93579.2		
2.	HUMAN INSULIN #1 OPTIMISTIC	28974.1		53605.1	82579.2		
3.	HUMAN INSULIN #1 REALISTIC	32724.7		55156.3	87881.0		
4.	HUMAN INSULIN #2 OPTIMISTIC	34255.7		52939.7	87195.4		
5.	HUMAN INSULIN #2 REALISTIC	38270.9		54810.8	93081.7		
6.	HUMAN INSULIN #3 OPTIMISTIC	41011.4		52613.8	91936.4		
7.	HUMAN INSULIN #3 REALISTIC	43689.4		57035.5	100724.9		
8.	ARTIFICIAL PANCREAS/FOREIGN	99425.8		49346.1	148772.0		135264.4
9.	ART. PAN./HUMAN #1 OPTIMISTIC	94477.4		47178.7	141656.1		119621.9
10.	ART. PAN./HUMAN #1 REALISTIC	95741.4		51745.9	147487.1		124313.2
11.	ART. PAN./HUMAN #2 OPTIMISTIC	100152.8	*	46815.1	146967.9	*	122673.1 **
12.	ART. PAN./HUMAN #2 REALISTIC	102367.6		47580.3	149947.8		125753.8
13.	ART. PAN./HUMAN #3 OPTIMISTIC	107634.9		48069.6	155705.4		128760.4
14.	ART. PAN./HUMAN #3 REALISTIC	108166.5		47695.2	155861.7		128916.5
15.	BETA-CELL TRANSPLANT	20778.2		43211.5	63989.7		

*COST ASSUMED EQUAL TO PRESENT
KIDNEY TRANSPLANT COSTS

**ASSUMES 50 PERCENT REDUCTION OF TREATMENT COSTS

PRESENT VALUE OF BENEFITS OF TREATMENT IN COMPARISON TO CONVENTIONAL TREATMENT FOR PRESENT U.S. DIABETIC POPULATION

Some, but not all, of the alternative treatments modeled compare favorably with the current, conventional treatment. Direct injection of human insulin can provide a present value benefit of up to $11 billion (1985 dollars) or a disbenefit of $7.1 billion, depending upon the assumptions employed. The advantages of the artificial pancreas appear to be subtantially outweighed by its cost; given our estimated inputs to the model, the artificial pancreas is clearly not economic. Beta cell transplants, if available at the reasonable costs assumed (see Appendix F), are extremely beneficial; this treatment, if successful, effectively eliminates the problem of diabetes for the patient.

Of course, space bioprocessing is only one possible means of obtaining these benefits. Laboratory synthesized human insulin, for example, may result even without space bioprocessing.

Thus, the benefits shown are really the benefits of the improved treatment and are independent of the technology that leads to the improvement.

PRESENT VALUE OF BENEFITS OF TREATMENT IN COMPARISON TO
CONVENTIONAL TREATMENT FOR PRESENT U.S. DIABETIC POPULATION

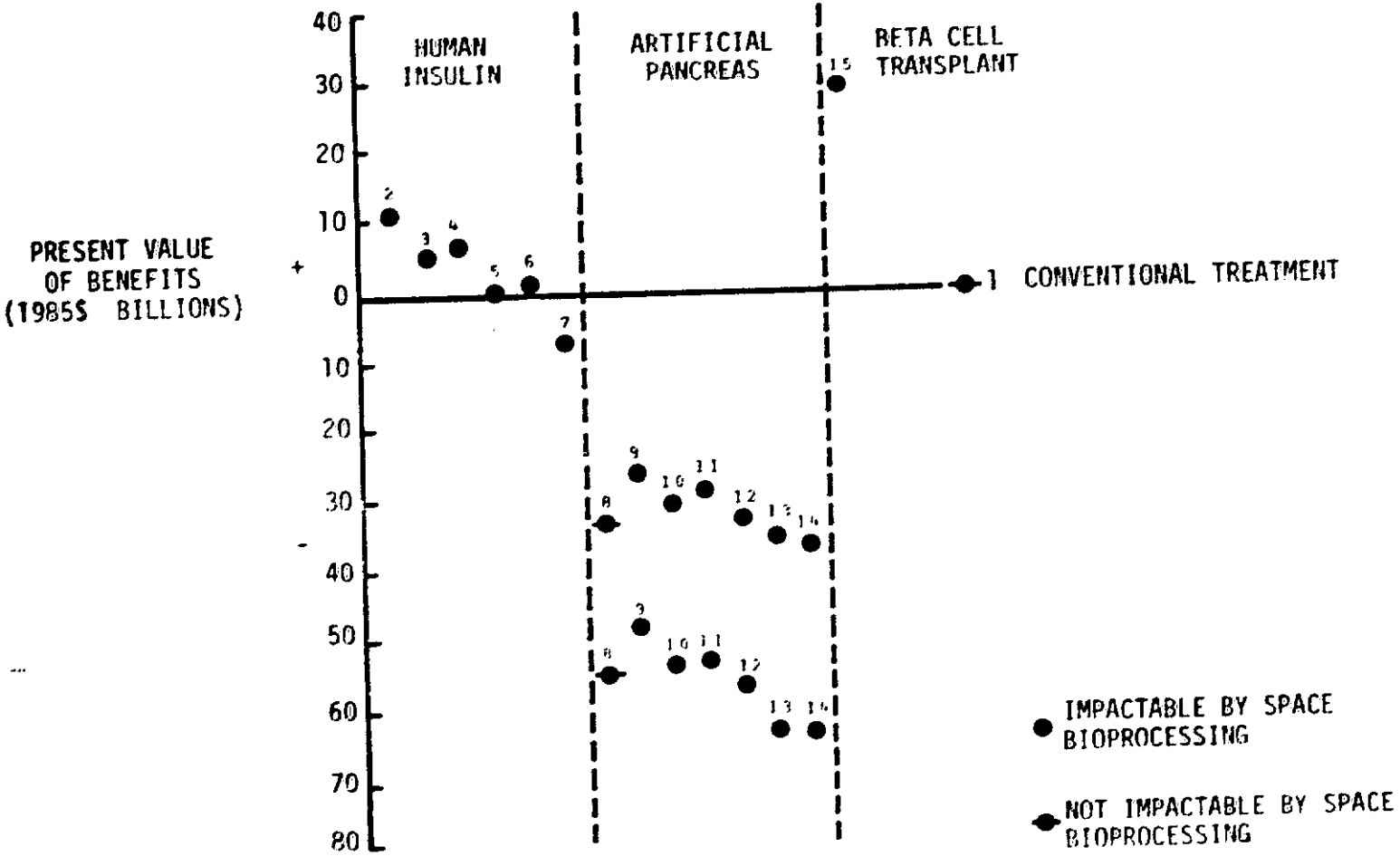
		PRESENT VALUE TOTAL BENEFIT (1985$, BILLIONS)		
1.	CONVENTIONAL (BOVINE/PROCINE INSULIN)	--		
2.	HUMAN INSULIN #1 OPTIMISTIC	11.0		
3.	HUMAN INSULIN #1 REALISTIC	5.7		
4.	HUMAN INSULIN #2 OPTIMISTIC	6.4		
5.	HUMAN INSULIN #2 REALISTIC	0.5		
6.	HUMAN INSULIN #3 OPTIMISTIC	1.7		
7.	HUMAN INSULIN #3 REALISTIC	-7.1		
8.	ARTIFICIAL PANCREAS/FOREIGN	-55.2	-33.3	
9.	ART. PAN./HUMAN #1 OPTIMISTIC	-48.2	-26.0	
10.	ART. PAN./HUMAN #1 REALISTIC	-53.9	-30.6	
11.	ART. PAN./HUMAN #2 OPTIMISTIC	-53.4	-29.1	* **
12.	ART. PAN./HUMAN #2 REALISTIC	-56.3	-32.1	
13.	ART. PAN./HUMAN #3 OPTIMISTIC	-62.2	-35.1	
14.	ART. PAN./HUMAN #3 REALISTIC	-62.3	-35.3	
15.	BETA-CELL TRANSPLANT	29.6		

*COST ASSUMED EQUAL TO PRESENT KIDNEY TRANSPLANT COSTS

**ASSUMES 50 PERCENT REDUCTION OF TREATMENT COSTS

BENEFITS OVER CONVENTIONAL TREATMENT
DIRECT AND INDIRECT COSTS

The opposite figure plots the expected benefits of each of the treatments considered relative to the conventional treatment (bovine/porcine insulin).


PRESENT VALUE
OF BENEFITS
(1985$ BILLIONS)
+
-
40
30
20
10
0
10
20
30
40
50
60
70
80
HUMAN
INSULIN
ARTIFICIAL
PANCREAS
BETA CELL
TRANSPLANT
1 CONVENTIONAL TREATMENT
IMPACTABLE BY SPACE
BIOPROCESSING
NOT IMPACTABLE BY SPACE
BIOPROCESSING

SUMMARY OF BENEFITS OF BETA CELL TRANSPLANTS

Presented here are more detailed results from the Beta cell treatment case. The number of diabetics in each age-of-onset class is listed as well as average age at death and the benefits of the treatment when compared with the conventional. As can be seen, the patients' lifetimes always increase. The largest benefit, of course, comes from the youngest age-of-onset class, primarily because of the large population size of that class, but also because theirs is a longer diabetic lifetime to be affected by the improved treatment.

SUMMARY OF BENEFITS OF BETA CELL TRANSPLANTS

AGE AT DIABETES ONSET (YEARS OF AGE)	NUMBER IN U.S. POPULATION (MILLIONS OF PERSONS)	AVERAGE AGE AT DEATH*	BENEFITS TO TREATMENT COSTS (MILLIONS OF DOLLARS)**	BENEFITS TO COMPLICATION COSTS (MILLIONS OF DOLLARS)**	BENEFITS TO MORTALITY COSTS (MILLIONS OF DOLLARS)**	TOTAL BENEFIT (MILLIONS OF DOLLARS)**
0 - 19	1.06	47.7 (41.9)	6667	4967	15031	26665
20 - 39	.06	64.6 (60.3)	365	329	559	1255
40 - 59	.06	73.6 (71.2)	282	485	335	1102
60+	.06	76.0 (75.9)	220	367	19	568
TOTAL***	1.24	51.1 (45.9)	7542	6148	15944	29633

*AVERAGE AT DEATH, BETA CELL TRANSPLANT (AVERAGE AGE AT DEATH, CONVENTIONAL TREATMENT)

**PRESENT VALUE IN 1985 DOLLARS

***DIFFERENCES BETWEEN COLUMN TOTALS AND TOTAL ROW ARE DUE TO ROUNDING ERRORS

PRELIMINARY FINDINGS

Our preliminary results show that there may be substantial benefit from the production of human insulin or the separation of Beta cells for transplantation. These benefits could be in the range of $11 billion (1985 dollars) to $29.6 billion (1985 dollars). Considerably more information on the costs of human insulin production or Beta cell separation must be obtained, however, before we can have confidence in the size of the ultimate benefit. Hopefully more information and consensus on the effects of insulin-antibody build-up in the body will also be forthcoming from medical researchers.

Both treatments clearly show the potential for substantial benefits and research in both should continue.

PRELIMINARY FINDINGS

- PRODUCTION OF HUMAN INSULIN
  - + POTENTIAL ECONOMIC AND SOCIAL BENEFITS MAY BE LARGE
  - + IMPROVED ESTIMATES OF COST OF PRODUCTION OF INSULIN AND IMPACT OF HUMAN INSULIN ON DIABETIC COMPLICATIONS REQUIRED TO REDUCE UNCERTAINTY IN BENEFIT ESTIMATES
- BETA-CELL TRANSPLANT
  - + LARGER POTENTIAL ECONOMIC AND SOCIAL BENEFITS
  - + SHORTER TIME REQUIRED TO ASSESS BENEFITS

SELECTED BIBLIOGRAPHY - DIABETES MELLITUS

AMA/Today's Health, Ronald W. Lamont-Havers, M.D., Surprising Findings About Diabetes, April 1968

ADA, Fact Sheet on Diabetes, 1974

ADA, Fact Sheet on Diabetes, 1975

ADA, Fact Sheet on Diabetes, 1976

Committee on Interstate and Foreign Commerce, National Diabetes Act of 1973, Hearings Before the Subcommittee on Public Health and Environment of the Committee on Interstate and Foreign Commerce, House of Representatives, 1973

Committee on Labor and Public Welfare, National Diabetes Research and Education Act, 1973, Hearing Before the Subcommittee on Labor and Public Welfare, U.S. Senate, 93rd Congress, 1973

Diabetologia, J. B. Herman, J. H. Medalie and U. Goldbourt, Differences in Cardiovascular Morbidity and Mortality Between Previously Known and Newly Diagnosed Adult Diabetics, 13, 220-234, 1977

Diabetologia, A. Marble, Late Complications of Diabetes: A Continuing Challenge, 12, 193-199, 1976

Garcia, Mariano J., Patricia M. McNamara, Tavia Gordon and William B. Kannell, Morbidity and Mortality in Diabetics in the Farmingham Population Sixteen Year Follow-up Study, Volume 23, No. 2, pps. 105-111, February 1974

Hospital Practice, Dr. Robert A. Good, Diabetes: The Relentless Progress Against a Relentless Disease, pps. 15-16, October 1977

Hospital Practice, John S. Najarian, Islet Cell Transplantation in Treatment of Diabetes, pps. 63-69, October 1977

Kleen, Harry, Editor, Complications of Diabetes, Edward Arnold (Publishers) Inc., London, 1975

Marble, Alexander, Pricilla White, Robert F. Bradley and Leo P. Krall, Editors, Joslin's Diabetes Mellitus, Lea & Febiger, Philadelphia, PA, June 1973 (11th Edition)

Maugh, Thomas H., II, The Two Faces of Diabetes, Xerox from: Science Year the World Book Science Annual 1978, Field Enterprises Educational Corporation, Chicago, IL, pps. 49-61, 1977

NIH, Report of the National Commission on Diabetes, Volume III, Part 1, Scope and Impact of Diabetes, Excerpts: Incidence and Prevalence Tables, Historical Trends in U.S., Deaths, Work-Years and Earnings Loss and Indirect Costs Due to Diabetes, Direct Costs, Length and Costs of Hospital Stays

New York Diabetes Association, Inc., Hospitals With Diabetes Clinics

New York Times, Ideas and Trends, In Summary: The Transfer of Genes That Make Insulin, May 29, 1977

New York Times, Harold M. Schmeck, Jr., U.S. Panel Rates Diabetes as Third-Highest Cause of Death; Long-Range Plan Urged to Fight Disease, Thursday, December 11, 1975

Quarterly Journal of Medicine, W. G. Oakley, D. A. Pyke, R. B. Tattersall and P. J. Watkins, Long-Term Diabetes, A Clinical Study of 92 Patients After 40 Years, New Series, XLIII, No. 169, pps. 145-156, January 1974

Science, Thomas H. Maugh II, Diabetes: Epidemiology Suggests A Viral Connection, Volume 188, April 25, 1975

Science, Thomas H. Maugh II, Diabetes (II): Model Systems Indicate Viruses A Cause, Volume 188, May 2, 1975

Science, Thomas H. Maugh II, Diabetes (III): New Hormones Promise More Effective Therapy, Volume 188, May 30, 1975

Science, Thomas H. Maugh II, The Pancreas, Volume 188, May 2, 1975

Science, Thomas H. Maugh II, What Is Diabetes? What Does It Do?, Volume 188, April 25, 1975

Science, Thomas H. Maugh II, Diabetics Therapy--Can New Techniques Halt Complications, Volume 190, December 26, 1975

Scitovsky, Anne A. and Nelda McCall, Changes in the Costs of Treatment of Selected Illnesses, 1951-1964-1971, Palo Alto Medical Research Foundation, Palo Alto, CA, August 1976

Sussman, Karl E., Complications of Insulin Therapy

U.S. Department of HEW, Diabetes Fact Book, 1961

U.S. Department of HEW, Diabetes Source Book, 1968

U.S. Department of HEW, Report of the National Commission on Diabetes to the Congress of the U.S., Volume III, Reports of Committees, Subcommittees and Workgroups, Part 3: Etiology and Pathology of Diabetes, DHEW Publication No. (NIH)77-1023, December 10, 1975

U.S. Department of HEW, Report of the National Commission on Diabetes to the Congress of the U.S., Volume III, Reports of Committees, Subcommittees and Workgroups, Part 2: Scope and Impact of Diabetes (II), DHEW Publication No. (NIH)77-1022, December 10, 1975

U.S. Department of HEW, Report of the National Commission on Diabetes to the Congress of the U.S., Volume III, Reports of Committees, Subcommittees and Workgroups, Part 1: Scope and Impact of Diabetes (I), DHEW Publication No. (NIH)77-1021, December 10, 1975

U.S. Department of HEW, Report of the National Commission on Diabetes to the Congress of the U.S., Volume II, Contributors to the Deliberations of the Commission, Part 1: Public Testimony, DHEW Publication No. (NIH)77-1019, December 10, 1975

U.S. Department of HEW, Estimating the Cost of Illness, Health Economics Series Number 6, Public Health Service Publication No. 947-6, Dorothy P. Rice, May 1966

U.S. Department of HEW, Diabetes Mellitus, DHEW Publication No. (NIH)76-854, Stefan S. Fajans, Editor, 1976

U.S. Department of HEW, Report of the National Commission on Diabetes to the Congress of the U.S., Volume III, Reports of Committees, Subcommittees and Workgroups, Part 4: Treatment of Diabetes, DHEW Publication No. (NIH)76-1024, December 10, 1975

U.S. Department of HEW, The Economic Cost of Illness Revisited, DHEW Publication No. (SSA)76-11703, Barbara S. Cooper and Dorothy P. Rice, February 1976

Diabetes and Its Management, Oakley, W. G., D. A. Pyke and K. W. Taylor, Blackwell Scientific Publications, London, 1973

The Kidney and Renal Tract, J. S. Cameron, J. T. Ireland and P. J. Walters in Complications of Diabetes, H. Kleen and J. Jarrett (Editors), Edward Arnold, London, 1975

APPENDIX A

HUMAN CAPITAL PROCEDURES/ASSUMPTIONS

HUMAN CAPITAL PROCEDURES/ASSUMPTIONS

- Mean earnings of full-time, year round employees obtained from Department of Labor, Monthly Labor Review, June 1976

White Men	$14,286
All Other Men	10,538
White Women	8,055
All Other Women	7,633

- Full-time employees represent the following percentage of all persons with work experience:

White Men	64.7%
All Other Men	56.5
White Women	41.0
All Other Women	43.6

Thus, this percentage was multiplied times the respective earnings.

- Mean earnings figures are then adjusted upward to account for wage supplements (employer contributions for social insurance, private pension and welfare funds). The uniform factor is 1.0776.

- Seventy percent of $4,000 was added to all women's earnings for housekeeping services: $400 was added for all males. $4,000 was imputed as housekeeper earnings for all retired females and $1,000 for men.

- A 6 percent discount rate was utilized.

- The present value of future earnings of a person at age a is defined by the following formula:

$$V_a = \sum_{n=a}^{85 \text{ \& over}} \frac{X_n W_n P_a^n}{(1+i)^{n-a}}$$

where:

- a is the midyear age for the given cohort of persons;
- X_n is the annual mean earnings for all persons in the category with earnings in an age group where the midpoint is age n;
- i is the discount rate;
- $W_n P_a^n$ is defined as the number of labor force years per person in an age group.

APPENDIX B

COST DATA FOR TREATMENT OF END STAGE RENAL DISEASE

PUBLIC SECTOR COSTS

DIALYSIS	1.	FIRST YEAR	
		80% OF HOSPITAL COSTS AFTER 3 MONTHS	$13,500.00
		80% OF DOCTORS' FEES	1,700.00
		20% OF PATIENTS ON WELFARE	1,000.00
			$16,200.00
	2.	SUBSEQUENT YEARS	
		80% OF HOSPITAL COSTS	$18,000.00
		80% OF DOCTORS' FEES	2,300.00
		20% OF PATIENTS ON WELFARE	1,000.00
			$21,300.00
TRANSPLANT	3.	FIRST YEAR	
		80% OF TRANSPLANT OPERATION (SEE TRANSPLANT COST BREAKDOWN)	$13,000.00
	4.	SUBSEQUENT YEARS	-0-
DEATHS	5.		-0-

PRIVATE SECTOR COSTS

DIALYSIS	1.	FIRST YEAR	
		CENTER DIALYSIS COST: $17,000 (70%)= (SEE CENTER DIALYSIS COST BREAKDOWN)	$11,900
		HOME DIALYSIS: $18,450 (30%) =	5,535
		AVERAGE	$17,435
	2.	SUBSEQUENT YEARS	
		CENTER DIALYSIS COST $11,850 x 70% =	$ 8,295
		HOME DIALYSIS COST $8,450 x 30% =	2,535
			$10,830
TRANSPLANT	3.	FIRST YEAR	
		20% OF AVERAGE OPERATION COST PLUS OTHER INCURRED COSTS	$ 9,250
	4.	SUBSEQUENT YEARS	
		COSTS	$ 5,100
DEATH	5.	DEATH	-0-

CENTER DIALYSIS COST BREAKDOWN ($)

	1ST YEAR	2ND YEAR
SURGERY FOR CONNECTION	500	0
COUNSELING (50% ASSUMING $1500/YEAR)	750	150
CHANGES IN DIET	200	200
JOB LOSS	4800	3000
RETRAINING	500	0
TUTORING	150	150
DIET SUPPLEMENTS	250	250
MOVING EXPENSES	250	0
SPOUSE OR FAMILY JOB LOSS OR REDUCTION	1000	750
TRANSPORTATION COSTS	750	750
DIALYSIS		
3-MONTH INITIAL PERIOD	1300	-
MEDICARE COVERAGE (80%)	4500	6000
M.D.		
3-MONTH INITIAL PERIOD	750	-
MEDICARE COVERAGE (80%)	430	600
	17,000	11,850

HOME DIALYSIS COST BREAKDOWN ($)

	1ST YEAR	SUBSEQUENT YEARS
LOSS OF SPOUSE WORK	500	500
CHAIR	250	-
PLUMBING	400	-
WATER	600	600
UTILITIES	100	100
TRAINING	4000	
M.D.	800	
MACHINE	4000	
MAINTENANCE	300	300
LAB	350	350
HOSPITAL BACKUP	3000	3000
COUNSELING	500	350
DIET CHANGES	200	200
JOB LOSS	1000	1000
RETRAINING	500	
TUTORING	100	100
DIET SUPPLEMENTS	250	250
SPOUSE OR FAMILY JOB LOSS	1000	1000
M.D.	600	600
	18,450	8,450

TRANSPLANT COST BREAKDOWN

	1ST YEAR	POST TRANSPLANT YEARS
FROM LIVING PERSON (30% OF TOTAL X $14,000)		
FROM CADAVER (70% OF TOTAL X $12,800)		
AVERAGE COST OF OPERATION TO PATIENT (20% OF TOTAL COST)	2600	-
WORK LOSS	1800	-
DONOR WORK LOSS	1300	-
MEDICATION AND M.D.'S	1500	3500
DIET CHANGES	200	200
COUNSELING	500	300
TUTORING	100	100
DIET SUPPLEMENTS	250	-
JOB DECREASE (TOO WEAK, CANNOT CONTINUE OLD SKILL)	1000	1000
	9,250	5,100

APPENDIX C

COST DATA FOR TREATMENT OF PULMONARY EMBOLISM

TRANSITION PROBABILITIES

SOURCES

- JAMES E. DALEN AND JOSEPH S. ALPERT, "NATURAL HISTORY OF PULMONARY EMBOLISM," PROGRESS IN CARDIOVASCULAR DISEASES, VOL. XVII, NO. 4. JANUARY-FEBRUARY, 1975. P. 259-270.
- AMERICAN HEART ASSOCIATION, "THE UROKINASE PULMONARY EMBOLISM TRIAL: A NATIONAL COOPERATIVE STUDY," MONOGRAPH #39, SUPPLEMENT TO CIRCULATION, APRIL , 1973.
- AMERICAN HEART ASSOCIATION, "UROKINASE-STREPTOKINASE EMBOLISM TRIAL: PHASE 2 RESULTS, " JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION, SEPT. 16, 1974, VOL. 229, NO. 12.

ASSUMPTIONS

- THE PROBABILITY OF DEATH FOR THOSE PATIENTS BEING TREATED WITH UROKINASE WILL DECREASE FROM .09 to .04.
- 80% OF PATIENTS WITH A DIAGNOSED PULMONARY EMBOLISM WILL BE TREATED WITH UROKINASE.
- A TREATMENT CONSISTING OF A PRECAUTIONARY INJECTION OF UROKINASE WILL BE GIVEN TO 30% OF UNDIAGNOSED PATIENTS. THIS INJECTION WOULD BE GIVEN BY MEDICS OR EMERGENCY ROOM PERSONNEL AS STANDARD PROCEDURE BUT NO DIAGNOSIS OF THE EMBOLISM WOULD TAKE PLACE (AS OFTEN OCCURS!).

COST ASSUMPTIONS FOR PULMONARY EMBOLISM

- NO EARNINGS ARE TABULATED, ONLY COSTS, BUT LOST EARNINGS ARE CONSIDERED A COST.
- EARNINGS (FOR LOST WAGES) WERE OBTAINED FROM THE DEPARTMENT OF LABOR.
- AVERAGE DAILY IN-PATIENT HOSPITAL COSTS FOR 1976 WERE OBTAINED FROM THE AMERICAN HOSPITAL ASSOCIATION.
- A 10 TO 1 COST REDUCTION FOR THE PRODUCTION OF UROKINASE WAS ASSUMED, BRINGING THE COST OF ONE DOSE DOWN TO $200.00.

COST BREAKDOWN BY TREATMENT STATE

1. PULMONARY EMBOLISM -

NONE, BY DEFINITION

2. NO DIAGNOSIS WITH TREATMENT

1 MONTH LOST EARNINGS	$913.75
HOSPITAL COSTS	
4 DAYS @ $158.39	633.56
UROKINASE	200.00
	$1747.31

(ROUNDED $1750.)

3. NO DIAGNOSIS AND NO TREATMENT

1 MONTH LOST EARNINGS	$913.75
HOSPITAL COSTS	
5 DAYS @ $158.39	791.95
	$1705.70

(ROUNDED $1700.)

4. POST PULMONARY EMBOLISM, NO PROPHYLAXIS

NONE

5. HEPARIN TREATMENT

M.D.	$1000.00
HOSPITAL COST	
5 DAYS INTENSIVE CARE	
@ $400/DAY	2000.00
9 MEDIUM CARE @ $158.39	1425.50
HEPARIN	20.00
LOST WAGES (1 MONTH)	913.75
LUNG SCAN	600.00
	$5939.25

(ROUNDED $5940.)

COST BREAKDOWN BY TREATMENT STATE (CONTINUED)

6. UROKINASE AND HEPARIN

M.D.	$1000.00
HOSPITAL COSTS	
3 DAYS INTENSIVE CARE @$400.	1200.00
9 DAYS MEDIUM CARE @$158.39	1425.50
LOST WAGES	913.75
LUNG SCAN	600.00
UROKINASE	200.00
	$5339.25

(ROUNDED $5340.)

7. SURGERY

HOSPITAL COSTS	
4 DAYS INTENSIVE CARE @$400.	$1600.00
12 DAYS MEDIUM CARE @$158.39	1900.88
HEPARIN	20.00
SURGEON	1900.00
INTERNIST	500.00
LUNG SCAN	600.00
LOST WAGES (2 MONTHS)	1827.50
	$8348.18

(ROUNDED $8350.)

8. POST PULMONARY EMBOLISM WITH PROPHYLAXIS

M.D.	$ 300.00
HEPARIN	20.00
LUNG SCAN	600.00
	$ 920.00

9. DEATH

APPENDIX D

COMPUTER PROGRAM LISTING FOR THE MODEL OF ESRD AND PULMONARY EMBOLISM

```
PIC      EXEC     P      ID=ECONWEST          11/01/77    09.33.02          PAGE 1
         VP/CSS   ---          NATIONAL CSS, INC. (SUNNYVALE DATA CENTER)

&TYPE ERASE                                                              BIO00010
FILEDEF 5 DSK A1 DATA                                                    BIO00020
FILEDEF 6 DSK A1 OUTPUT LRECL 132                                        BIO00030
RUN BIG MAT NEWST                                                        BIO00040
FILEDEF * CLEAR                                                          BIO00050
```

```
      INTEGER YRS(15),A(15),NY(15),Z(15),CS,CSP,NITS(15)                BI000010
      REAL P(15,15,15),C(15),CC(100),AVEA(15),SGA(15),AVEZ(15),SGZ(15), BI000020
     1 AVENY(15),SGNY(15),AVECC(100),SGCC(100),DUM1(450),DUM2(450),     BI000030
     2 DCC(100),AVEDCC(100),SGDCC(100),                                 BI000040
     3 PRO:(15),D(15),DD(100),AVEDD(100),SGDD(100),DDD(100),AVEDDD(100),BI000050
     4 SGDDD(100)                                                       BI000060
      EQUIVALENCE (DUM1,AVEALP),(DUM1(2),AVEA),(DUM1(17),AVEZ),         BI000070
     1 (DUM1(32),AVENY),(DUM1(47),AVETCC),(DUM1(48),AVEDTC),           BI000080
     2 (DUM1(49),AVECC),(DUM1(149),AVEDCC),                            BI000090
     3 (DUM1(249),AVETDD),(DUM1(250),AVEDTD),(DUM1(251),AVEDD),        BI000100
     4 (DUM1(351),AVEDDD)                                              BI000110
      EQUIVALENCE (DUM2,SGALP),(DUM2(2),S.A),(DUM2(17),S.Z),           BI000120
     1 (DUM2(32),SGNY),(DUM2(47),SGTCC),(DUM2(48),SGDTCC),             BI000130
     2 (DUM2(49),S.CC),(DUM2(149),SGDCC),                              BI000140
     3 (DUM2(249),SGTDD),(DUM2(250),SGDTD),(DUM2(251),SGDD),           BI000150
     4 (DUM2(351),SGDDD)                                               BI000160
      READ(5,100)NS                                                    BI000170
      IF(NS.LT.2.OR.NS.GT.15) STOP 999                                 BI000180
      NS1 = NS - 1                                                     BI000190
      NS2 = NS - 2                                                     BI000200
      DO 99 L=1,450                                                    BI000210
      DUM1(L) = 0.                                                     BI000220
      DUM2(L) = 0.                                                     BI000230
99    CONTINUE                                                         BI000240
      READ(5,100) NIT                                                  BI000250
100   FORMAT(I5,F5.3)                                                  BI000260
      READ(5,100) MAXYR,DISC                                           BI000270
      NYR1 = MAXYR - 1                                                 BI000280
      READ(5,101) (C(I),I=1,NS)                                        BI000290
101   FORMAT(8F10.2)                                                   BI000300
      READ(5,101) (D(I),I=1,NS)                                        BI000310
      DO 10 I=1,MAXYR                                                  BI000320
      READ(5,100) YRS(I)                                               BI000330
      DO 111 J=1,NS                                                    BI000340
      READ(5,1022) (P(I,J,K),K=1,NS)                                   BI000350
1022  FORMAT(15F5.2)                                                   BI000360
111   CONTINUE                                                         BI000370
      IF(I.GT.1) YRS(I) = YRS(I-1) + YRS(I)                            BI000380
      IF(YRS(I).GE.MAXYR) GO TO 21                                     BI000390
10    CONTINUE                                                         BI000400
21    NI = I                                                           BI000410
      DO 125 L=1,NS                                                    BI000420
      NITS(I) = 0                                                      BI000430
125   CONTINUE                                                         BI000440
      DO 200 L=1,NIT                                                   BI000450
      DO 130 I=1,MXYR1                                                 BI000460
      CC(I) = 0.                                                       BI000470
      DCC(I) = 0.                                                      BI000480
      DD(I) = 0.                                                       BI000490
      DDD(I) = 0.                                                      BI000500
130   CONTINUE                                                         BI000510
      TCE = 0.                                                         BI000520
      DTCC = 0.                                                        BI000530
      TCC = 0.                                                         BI000540
      DTCC = 0.                                                        BI000550
```

```
      DO 22 I=1,NS                                                      BI000560
      A(I) = MAXYR + 1                                                  BI000570
      NY(I) = 0                                                         BI000580
      Z(I) = 0                                                          BI000590
22    CONTINUE                                                          BI000600
25    M = 1                                                             BI000610
      Z(1) = 1                                                          BI000620
      CS = 1                                                            BI000630
30    I= MAT(M,YRS,MAXYR,NS)                                            BI000640
      X = RAN(135713)                                                   BI000650
      CSR = MF.ST(R,I,CS,M,NI,NS)                                       BI000660
      A(CSR) = MIN0(A(CSR),M)                                           BI000670
      IF(CSR.EQ.NS) GO TO 150                                           BI000680
      NY(CSR) = NY(CSR) + 1                                             BI000690
      IF(CS.NE.CSR) Z(CSR) = Z(CSR) + 1                                 BI000700
      CC(M) = C(CSR)                                                    BI000710
      DD(M) = D(CSR)                                                    BI000720
      CCC(M) = C(CSR)*(1.+DISC)**(-(M-1))                               BI000730
      DDD(M) = D(CSR)*(1.+DISC)**(-(M-1))                               BI000740
      TCC = TCC + CC(M)                                                 BI000750
      DTCC = DTCC + CCC(M)                                              BI000760
      TDD = TDD + DD(M)                                                 BI000770
      DTDD = DTDD + DDD(M)                                              BI000780
      M = M + 1                                                         BI000790
      CS = CSR                                                          BI000800
      IF(M.LT.MAXYR) GO TO 30                                           BI000810
      CSR = NS                                                          BI000820
150   ALPHA = M                                                         BI000830
      A(CSR) = M                                                        BI000840
      DO 155 I=1,NS                                                     BI000850
      IF(I.EQ.1) GO TO 157                                              BI000860
      IF(A(I).EQ.MAXYR+1) A(I) = M                                      BI000870
      IF(A(I).EQ.0) Z(I) = 0                                            BI000880
153   IF(Z(I).NE.0) NITS(I) = NITS(I) + 1                               BI000890
155   CONTINUE                                                          BI000900
      AVETCC = AVETCC + TCC                                             BI000910
      SQTCC = SQTCC + TCC**2                                            BI000920
      AVETDD = AVETDD + TDD                                             BI000930
      SQTDD = SQTDD + TDD**2                                            BI000940
      AVEALP = AVEALP + ALPHA                                           BI000950
      SQALP = SQALP + ALPHA**2                                          BI000960
      AVEDTC = AVEDTC + DTCC                                            BI000970
      SQDTCC = SQDTCC + DTCC**2                                         BI000980
      AVEDTD = AVEDTD + DTDD                                            BI000990
      SQDTD = SQDTD + DTDD**2                                           BI001000
      DO 160 I=1,NS                                                     BI001010
      AVEA(I) = AVEA(I) + A(I)                                          BI001020
      SQA(I) = SQA(I) + A(I)**2                                         BI001030
      AVEZ(I) = AVEZ(I) + Z(I)                                          BI001040
      SQZ(I) = SQZ(I) + Z(I)**2                                         BI001050
      AVENY(I) = AVENY(I) + NY(I)                                       BI001060
      SQNY(I) = SQNY(I) + NY(I)**2                                      BI001070
160   CONTINUE                                                          BI001080
      DO 170 I=1,MAXYR+1                                                BI001090
      AVEDCC(I) = AVEDCC(I) + DCC(I)                                    BI001100
```

```
      SQDCC(I) = SQDCC(I) + DCC(I)**2                                          BI001110
      AVECC(I) = AVECC(I) + CC(I)                                              BI001120
      SQCC(I) = SQCC(I) + CC(I)**2                                             BI001130
      AVEDDD(I) = AVEDDD(I) + DDD(I)                                           BI001140
      SQDDD(I) = SQDDD(I) + DDD(I)**2                                          BI001150
      AVEDD(I) = AVEDD(I) + DD(I)                                              BI001160
      SQDD(I) = SQDD(I) + DD(I)**2                                             BI001170
  170 CONTINUE                                                                 BI001180
  200 CONTINUE                                                                 BI001190
      AVEALP = AVEALP/NIT                                                      BI001200
      SGALP = SQRT((SGALP-NIT*AVEALP**2)/(NIT-1))                              BI001210
      DO 250 I=1,NS                                                            BI001220
      PROB(I) = 1.0*NITS(I)/NIT                                                BI001230
      IF(NITS(I).NE.0) AVEA(I) = AVEA(I)/NITS(I)                               BI001240
      IF(NITS(I).GT.1) SGA(I) = SQRT((SGA(I)-NITS(I)*AVEA(I)**2)/(NITS(I)      BI001250
     1 I)-1))                                                                  BI001260
      IF(NITS(I).NE.0) AVEZ(I) = AVEZ(I)/NITS(I)                               BI001270
      IF(NITS(I).GT.1) SGZ(I) = SQRT((SGZ(I)-NITS(I)*AVEZ(I)**2)/(NITS(I)      BI001280
     1 )-1))                                                                   BI001290
  250 CONTINUE                                                                 BI001300
      DO 300 L=32,450                                                          BI001310
      DUM1(L) = DUM1(L)/NIT                                                    BI001320
      IF((DUM2(L)-NIT*DUM1(L)**2).LE.0.) GO TO 300                             BI001330
      DUM2(L) = SQRT((DUM2(L) - NIT*DUM1(L)**2)/(NIT-1))                       BI001340
  300 CONTINUE                                                                 BI001350
      WRITE(6,6101)                                                            BI001360
 6101 FORMAT(T13,*PROB*,6*/T13,*ENTERING*/T3,*STATE*,5X,*STATE*/              BI001370
     1 T2,8(1H*),3X,8(1H*))                                                    BI001380
      WRITE(6,6102) (J,PROB(J),J=1,NS1)                                        BI001390
 6102 FORMAT(I5,F14.3)                                                         BI001400
      WRITE(6,6002)                                                            BI001410
 6002 FORMAT(//T27,*STANDARD*/T3,*VARIABLE*,3X,*MEAN*,7X,*DEVIATION*/         BI001420
     1 1X,10(1H*),2X,8(1H*),5X,8(1H*)/)                                        BI001430
      WRITE(6,6603) DUM1(1),DUM2(1),(L,DUM1(L+1),DUM2(L+1),L=2,NS1)            BI001440
 6603 FORMAT(* AGE DEATH*,F9.2,F14.2//                                         BI001450
     1 (* AGE IN S*,I2,F9.2,F14.2))                                            BI001460
      WRITE(6,6604) (L,DUM1(L+16),DUM2(L+16),L=1,NS1)                          BI001470
 6604 FORMAT(//(* S   IN S*,I2,F9.2,F14.2))                                    BI001480
      WRITE(6,6605)(L,DUM1(L+31),DUM2(L+31),L=1,NS1)                           BI001490
 6605 FORMAT(//(* YRS IN S*,I2,F9.2,F14.2))                                    BI001500
      WRITE(6,6606)(DUM1(L),DUM2(L),L=47,48),                                  BI001510
     2 (DUM1(L),DUM2(L),L=243,250)                                             BI001520
 6606 FORMAT(//* TOT COST*,F10.2,F14.2///* TOT DCOST*,F9.2,F14.2//            BI001530
     1 /* TOT IND C*,F9.2,F14.2///* TOT IND D*,F9.2,F14.2/)                   BI001540
      WRITE(6,6104)                                                            BI001550
 6104 FORMAT(//T23,*GOVERNMENT COSTS*,T93,*INDIVIDUAL COSTS*/                  BI001560
     1 T2,59(1H*),T72,59(1H*))                                                 BI001570
      WRITE(6,6006) DISC,DISC                                                  BI001580
 6006 FORMAT(//T41,*DISCOUNTED AT*,F5.2,T111,*DISCOUNTED AT*,F5.2/T39,*       BI001590
     1 22(1H*),T109,22(1H*))                                                   BI001600
      WRITE(6,6004)                                                            BI001610
 6004 FORMAT(*  COST AT*,T27,*STANDARD*,T52,*STANDARD*,T72,* COST AT*,         BI001620
     1 T2/,*STANDARD*,T122,*STANDARD*/                                         BI001630
     1 4X,*AGE*,T16,*MEAN*,T27,*DEVIATION*,T41,*MEAN*,T52,*DEVIATION*,         BI001640
     2 T93,*AGE*,T86,*MEAN*,T97,*DEVIATION*,T111,*MEAN*,T122,*DEVIATION*)      BI001650
```

```
     2 /1X,9(1H*),3X,8(1H*),5X,9(1H*),3X,8(1H*),5X,9(1H*),                    BIC01660
     3 T72,9(1H*),3X,5(1H*),5X,9(1H*),3X,8(1H*),5X,9(1H*)//)                  BIC01670
       WRITE(6,6005) (L,DUM1(L+48),DUM2(L+48),DUM1(L+48+100),DUM2(L+          BIC01680
     1 48+100),L,DUM1(L+250),DUM2(L+250),DUM1(L+250+100),DUM2(L+250+100       BIC01690
     2 ),L=1,MXYPM1)                                                          BIC01700
6005  FORMAT(10(I5,F15.2,F14.2,F11.2,F14.2,T71,I6,F15.2,F14.2,F11.2,F14.      BIC01710
     1 2//)/)                                                                 BIC01720
      STOP                                                                    BIC01730
      END                                                                     BIC01740
```

```
&TYPE ERROR                                                    BI0000010
FILEDEF 8 DSK &1 DATA                                          BI0000020
FILEDEF 9 DSK BIOSORT DATA LRECL 100                           BI0000030
FILEDEF 6 DSK BIOOUT DATA LRECL 132                            BI0000040
LOAD BIO MAT NEWST                                             BI0000050
DEBUG                                                          BI0000060
FILEDEF * CLEAR                                                BI0000070
```

```
      FUNCTION NEWST(F,I,CS,X,N,I,S)                                    NI000010
      INTEGER CS                                                        NI000020
      REAL F(15,15,15)                                                  NI000030
      Z = 0.                                                            NI000040
      DO 10 J=1,NS                                                      NI000050
      Z = Z + F(I,CS,J)                                                 NI000060
      IF(Z.GT.X) GO TO 20                                               NI000070
10    CONTINUE                                                          NI000080
      STOP 456                                                          NI000090
20    NEWST = J                                                         NI000100
      RETURN                                                            NI000110
      END                                                               NI000120
```

APPENDIX E

DIABETES TRANSITIONAL PROBABILITY MODEL PROGRAM COMPUTER LISTING

```
1010 DIM S[10],A[20],PS[10,20],C[20,2],DS[10,20]
1020 DIM B[10],E[10],F[10],G[10],H[10],X[20],R[10,2],U[10],V[20]
1030 DIM L[4]
1040 L[1]=10
1050 L[2]=30
1060 L[3]=50
1070 L[4]=60
1080 FILES PROB,COST,MORT,CCOMP,TREAT2,WAGES
1090 MAT READ # 2;C
1100 MAT READ # 4;R
1110 MAT READ # 6;V
1120 DISP "ENTER NUMBER OF ITERATIONS"
1130 INPUT N9
1140 FOR L=1 TO 4
1150 Q=L[L]
1160 FORMAT "THE NUMBER OF ITERATIONS IS",F6.0
1170 M=5
1180 DISP "ENTER AGE AT ONSET";
1190 REM     INPUT Q
1200 FOR Q2=1 TO 15
1210 PRINT LIN2,"**************************************************",LIN1
1220 WRITE (2,1160)N9
1230 FORMAT "TREATMENT COSTS ",2F10.2
1240 T8=INT(Q/5)
1250 T9=0
1260 IF Q >= 60 THEN 1280
1270 T9=INT((60-Q)/5)
1280 WRITE (2,1290)Q
1290 FORMAT "THE AGE AT ONSET IS",F6.0
1300 DISP "ENTER TREATMENT NUMBER";
1310 REM    INPUT Q2
1320 MAT READ # 5,Q2;U
1330 WRITE (2,1350)Q2
1340 WRITE (2,1230)C[Q2,1],C[Q2,2]
1350 FORMAT "THE TREATMENT NUMBER IS",F6.0
1360 F9=INT(Q/20)+1
1370 IF F9<5 THEN 1390
1380 F9=4
1390 MAT READ # 1,(F9-1)*4+1;P
1400 FOR I=1 TO 10
1410 FOR J=1 TO 5
1420 P[I,J]=P[I,J]*U[I]
1430 NEXT J
1440 NEXT I
1450 FOR I=1 TO 10
1460 D[I,1]=P[I,1]
1470 FOR J=2 TO 5
1480 D[I,J]=P[I,J]-P[I,J-1]
1490 NEXT J
1500 Z=P[I,1]
1510 FOR J=2 TO 5
```

```
1520 P[I,J]=D[I,J]/(1-Z)
1530 Z=Z+D[I,J]
1540 NEXT J
1550 FOR J=6 TO 20
1560 P[I,J]=0
1570 NEXT J
1580 NEXT I
1590 PRINT LIN1,"PROBABILITY TABLE"
1600 FOR I=1 TO 5
1610 FOR J=1 TO 5
1620 WRITE (2,1630)P[I,J];
1630 FORMAT F7.3
1640 NEXT J
1650 PRINT " "
1660 NEXT I
1670 MAT READ # 3,(F9-1)*4+1;D
1680 MAT X=ZER
1690 MAT A=ZER
1700 MAT B=ZER
1710 MAT E=ZER
1720 MAT F=ZER
1730 MAT G=ZER
1740 N=0
1750 N=N+1
1760 IF N>N9 THEN 2280
1770 DISP "ITER"N
1780 MAT S=ZER
1790 MAT H=ZER
1800 Y=0
1810 Z=1
1820 Y=Y+1
1830 Z9=Z
1840 A[Y]=A[Y]+1
1850 S=C[Q2,1]
1860 IF Y=1 THEN 1880
1870 S=C[Q2,2]
1880 FOR I=1 TO M
1890 IF S[I]=1 THEN 1980
1900 IF RND(Q)>P[I,Y] THEN 1990
1910 S=S+R[I,1]
1920 S[I]=1
1930 E[I]=E[I]+1
1940 F[I]=F[I]+Y
1950 H[I]=Y
1960 Z=Z+1
1970 GOTO 1990
1980 S=S+R[I,2]
1990 NEXT I
2000 IF Z<3 OR Y>T9 THEN 2170
2010 IF S[6]=1 THEN 2140
2020 T2=0.25
```

```
2030 IF Z=3 THEN 2050
2040 T2=0.35
2050 IF RNDQ>T2 THEN 2170
2060 Z=Z+1
2070 S[6]=1
2080 E[6]=E[6]+1
2090 H[6]=Y
2100 F[6]=F[6]+Y
2110 S=S+C[20,1]
2120 IF RNDQ>0.7 THEN 2170
2130 GOTO 2150
2140 S=S+C[20,2]
2150 X[Y]=X[Y]+S
2160 GOTO 2190
2170 X[Y]=X[Y]+S
2180 IF RNDQ>(D[Z,Y]+D[Z9,Y])*0.5 THEN 1820
2190 B[Z]=B[Z]+1
2200 Y9=Y+0.5
2210 FOR I=1 TO M+1
2220 IF H[I]=0 THEN 2240
2230 G[I]=G[I]+Y9-H[I]
2240 NEXT I
2250 IF H[5]=0 THEN 2270
2260 G[5]=G[5]+0.5
2270 GOTO 1750
2280 S1=S2=S7=0
2290 PRINT LIN1,"   DURATION              DEATHS   LOST WAGES    AVE. COSTS"
2300 FOR Y=1 TO 20
2310 IF A[Y]=0 THEN 2400
2320 T7=Y+T8
2330 D=A[Y]-A[Y+1]
2340 WRITE (2,2350)(Y-1)*5+1,Y*5,D,D*V[T7],X[Y]/A[Y]
2350 FORMAT F5.0,"  -",F4.0,F12.0,2F14.0
2360 S1=S1+D*V[T7]
2370 S2=S2+D*V[T7]*V[T7]
2380 S7=S7+X[Y]
2390 NEXT Y
2400 S5=S6=0
2410 FOR Y=1 TO 20
2420 IF A[Y]=0 THEN 2460
2430 S5=S5+(A[Y]-A[Y+1])*Y*5
2440 S6=S6+(A[Y]-A[Y+1])*Y*Y*25
2450 NEXT Y
2460 S5=S5/N9
2470 WRITE (2,2480)S1/N9
2480 FORMAT /,"AVE LOST WAGES",F12.0
2490 S8=1
2500 IF S5 >= 5 THEN 2520
2510 S8=S5/5
2520 S4=S8*C[Q2,1]+(S5-5*S8)*C[Q2,2]/5
2530 WRITE (2,2540)S4,(S7/N9-S4)
```

```
2540 FORMAT "TREATMENT COST",F12.0,/,"COMPLICATION COST",F9.0
2550 WRITE (2,2560)S7/N9
2560 FORMAT "AVE TOTAL COST",F12.0
2570 S6=S6/N9
2580 V=(S6-S5*S5)^0.5
2590 WRITE (2,2600)S5+0,V
2600 FORMAT /,"AGE AT DEATH",2F10.1
2610 PRINT
2620 S1=S1/N9
2630 S2=S2/N9
2640 S3=(S2-S1*S1)^0.5
2650 N9=N-1
2660 PRINT "PROB OF GETTING NUMBER OF COMPLICATIONS"
2670 FOR I=1 TO 7
2680 P=B[I]/N9
2690 WRITE (2,2700)(I-1),P*100,100*((P*(1-P))^0.5)
2700 FORMAT F8.0,2F10.1
2710 NEXT I
2720 PRINT
2730 PRINT "PROB OF GETTING SPECIFIC COMPLICATION"
2740 FOR I=1 TO M+1
2750 P=E[I]/N9
2760 WRITE (2,2700)I,100*P,100*((P*(1-P))^0.5)
2770 NEXT I
2780 PRINT
2790 PRINT "AGE GETTING COMPLICATION"
2800 FOR I=1 TO M+1
2810 S=0
2820 IF E[I]=0 THEN 2860
2830 S=5*F[I]/E[I]+Q-2.5
2840 IF I#5 THEN 2860
2850 S=S-2.5
2860 WRITE (2,2700)I,S
2870 NEXT I
2880 PRINT
2890 PRINT "NUMBER OF YEARS WITH COMPLICATION"
2900 FOR I=1 TO M+1
2910 S=0
2920 IF G[I]=0 THEN 2940
2930 S=G[I]/E[I]*5
2940 WRITE (2,2700)I,S
2950 NEXT I
2960 NEXT Q2
2970 NEXT L
2980 END
```

APPENDIX F

COST OF DIABETES TREATMENT

PRECEDING PAGE BLANK NOT FILMED

COST PER PATIENT OF INITIAL DIABETES TREATMENT (TREATMENT AT ONSET)

7 DAYS HOSPITAL	$1,225
DIABETES TREATMENT	215
WORK LOSS (14 DAYS)	308
	$1,748

ANNUAL COST PER PATIENT OF CONVENTIONAL TREATMENT

INSULIN AND MEDICAL SUPPLY	$115
2 CLINIC VISITS	96
WORK LOSS (ONE DAY)	22
DIET CHANGE	200
TUTORING	100
	$533

ANNUAL PER PATIENT COST OF HUMAN INSULIN

INSULIN & MEDICAL SUPPLY	$115	$335	$ 610
2 CLINIC VISITS	96	96	96
WORK LOSS (1 DAY)	22	22	22
DIET CHANGE	200	200	200
TUTORING	100	100	100
	$533	$753	$1,028

ANNUAL COST PER PATIENT OF ARTIFICIAL
PANCREAS/FOREIGN INSULIN TREATMENT

	FIRST YEAR	POST YEAR
OPERATION AND DEVICE	$12,800	$ -
WORK LOSS	1,800	-
MEDICATION (EXCEPT INSULIN) AND M.D.'s	1,500	500
DIET CHANGES	200	200
COUNSELING	500	300
TUTORING	100	100
DIET SUPPLEMENTS	250	-
JOB DECREASE	1,000	1,000
INSULIN AND MEDICAL SUPPLIES	115	115
	$18,265	$2,215

ANNUAL COST PER PATIENT OF BETA CELL TRANSPLANT

	FIRST YEAR	POST YEAR
OPERATION	$6000	
WORK LOSS	374	
CLINIC VISITS (2)	96	$ 96
WORK LOSS (ONE DAY)	22	22
DIET AND TUTORING	600	500
	$7092	$618

ANNUAL COST PER PATIENT OF ARTIFICIAL PANCREAS WITH HUMAN INSULIN

	FIRST YEAR HUMAN #1	FIRST YEAR HUMAN #2	FIRST YEAR HUMAN #3	POST YEAR HUMAN #1	POST YEAR HUMAN #2	POST YEAR HUMAN #3
OPERATION AND DEVICE	$12,800	$12,800	$12,800	-	-	-
WORK LOSS	1,800	1,800	1,800	-	-	-
MEDICATION (EXCEPT INSULIN) AND PHYSICIANS	1,500	1,500	1,500	$ 500	$ 500	$ 500
DIET CHANGES	200	200	200	200	200	200
COUNSELING	500	500	500	300	300	300
TUTORING	100	100	100	100	100	100
DIET SUPPLEMENTS	250	250	250	-	-	-
JOB DECREASE	1,000	1,000	1,000	1,000	1,000	1,000
INSULIN AND MEDICAL SUPPLIES	115	335	610	115	335	610
TOTAL	$18,265	$18,485	$18,760	$2,215	$2,435	$2,710

COST PER PATIENT OF PANCREAS TRANSPLANT

	FIRST YEAR	POST YEAR
OPERATION (CADAVER)	$12,800	
WORK LOSS	1,800	
MEDICATION & M.D.'S	1,500	$3,500
DIET CHANGES	200	200
COUNSELING	500	300
TUTORING	100	100
DIET SUPPLEMENTS	250	--
JOB DECREASE (UNABLE TO CONTINUE OLD SKILL)	1,000	1,000
	$18,150	$5,100

APPENDIX G

COST OF DIABETIC COMPLICATION CARE

COST OF DIABETIC RETINOPATHY

COST PER PATIENT--DIRECT AND INDIRECT

$625 FIRST 5-YEAR PERIOD

$1250 SUBSEQUENT 5-YEAR PERIOD

SOURCE: DIABETES MELLITUS, NATIONAL INSTITUTES OF HEALTH, [DHEW PUBLICATION NO. (NIH) 76-854], STEFANS FAJANS, M.D., EDITOR, 1976.

COST OF CARDIOVASCULAR COMPLICATIONS

COST PER PATIENT--DIRECT AND INDIRECT

$9,940 FIRST 5-YEAR PERIOD

$11,665 SUBSEQUENT 5-YEAR PERIODS

- DIRECT COST, COST OF MYOCARDIAL INFARCTION, CHANGES IN THE COSTS OF TREATMENT OF SELECTED ILLNESSES, ANNE A. SCITOVSKY AND NELDA McCALL, HEALTH POLICY PROGRAM, UNIVERSITY OF CALIFORNIA, SAN FRANCISCO, 1975

- INDIRECT COSTS 37.2 DAYS LOST INCOME FOR INITIAL TREATMENT

  REDUCTION OF SUBSEQUENT INCOME BY ONE-THIRD

COST OF PERIPHERAL VASCULAR COMPLICATIONS

COST PER PATIENT--DIRECT AND INDIRECT

$20,500 FIRST 5-YEAR PERIOD
$35,000 SUBSEQUENT 5-YEAR PERIOD

- DIRECT COSTS OF FIRST YEAR TREATMENT $3000 (VERY OFTEN AMPUTATIONS)
- INDIRECT COSTS--LOSS OF AVERAGE EARNING CAPACITY

COST OF NEPHROPATHY TREATMENT

PER PATIENT COSTS DIRECT AND INDIRECT

$2,500 FIRST 5-YEAR PERIOD
$5,000 SUBSEQUENT 5-YEAR PERIODS

SOURCES: PREVALENCE OF CHRONIC CONDITIONS OF THE GENITOURINARY, NERVOUS, ENDOCRINE, METABOLIC AND BLOOD AND BLOOD-FORMING SYSTEMS AND OF OTHER SELECTED CHRONIC CONDITIONS UNITED STATES, 1973, HEALTH RESOURCES ADMINISTRATION, 1977, DHEW PUBLICATION NO. (HRA) 77-1536.

THE ECONOMIC COST OF ILLNESS REVISITED, BARBARA S. COOPER AND DOROTHY P. RICE, 1976, DHEW PUBLICATION NO. (SSA) 76-11703.

COST OF INSULIN RESISTANCE

COST PER PATIENT DIRECT AND INDIRECT

$14,433 FIRST 5-YEAR PERIOD

$12,685 SUBSEQUENT 5-YEAR PERIODS

BREAKDOWN:

	FIRST YEAR	POST YEAR
ADDITIONAL INSULIN (800 UNITS/DAY)	$1,460	$1,460
ADDITIONAL CLINIC VISITS (4/YEAR)	192	192
NORMAL DIABETES TREATMENT	533	533
WORK LOSS	660	352
HOSPTIAL STAY	1,225	
SPECIFIC TREATMENTS	215	
	$4,285	$2,537

SOURCES: MEDICAL ADVISORS

JOSLIN CLINIC